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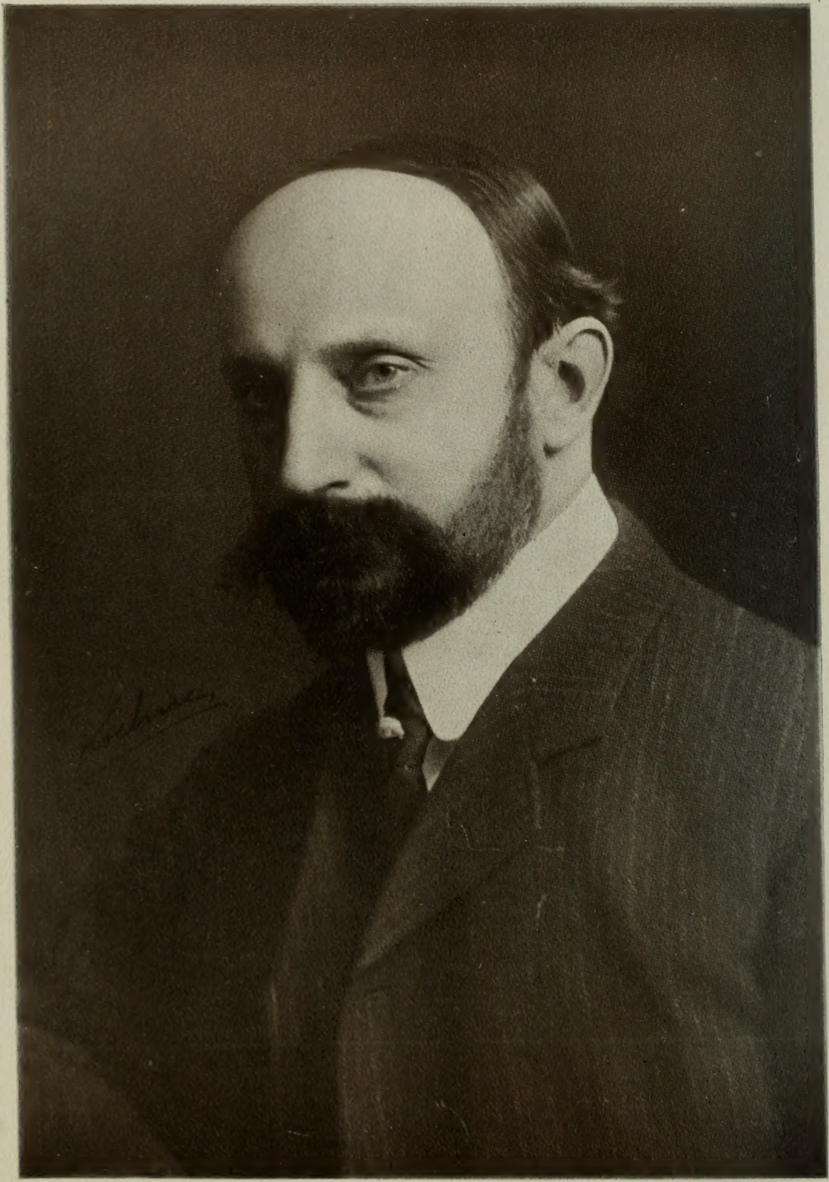

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Ralph Modjeski

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VOL. VIII. FEBRUARY, 1903. NO. 1.

CLXIII.

COPPER MINING IN UPPER MICHIGAN.

By J. F. Jackson, M. W. S. E.

Read December 3, 1902.

There are in the vicinity of Chicago two great industries which lie at the base of the pyramid of our great national prosperity, and without which our tremendous development of machinery, steel and electrical manufactures would have been impossible. I refer to the great business of mining iron ore and copper which is conducted just north of the city; that is within a night's ride in a comfortable sleeping car. This map (Fig. 1) will show what is meant. Here, bordering the greatest lake in the world, are iron mines of such vast extent and producing such immense quantities of ore as to almost stagger belief. The engineering features developed in this region have been waiting for some years for adequate description from an engineering point of view. The purpose of this paper. however, is not to write of iron mines, but to call attention to some features of a narrow peninsula which projects into the troubled bosom of Kitchigami, giving it the appearance of suffering severe pain. Many of us have only a vague memory that our old school geographies showed—a small peninsula extending into Lake Superior, upon which the word copper was marked. Although copper has been mined in Upper Michigan since 1844, when Chicago and Milwaukee were hardly more than small villages, the average Chicago citizen knows but little about it, due to the fact that practically all copper mining enterprises have been financed and managed from Boston. With this introduction I will undertake to present to you some replies to questions which naturally arise in an inquiring engineering mind when its possessor first visits the copper country, or the "lake" as a Boston man would call it.

The copper range, or mineral-bearing formation, which is about three miles in width, extends from Keweenaw point in a southwesterly direction about 60 miles to Ontonagon. Its course is generally parallel to the shore of Lake Superior. Copper is also found

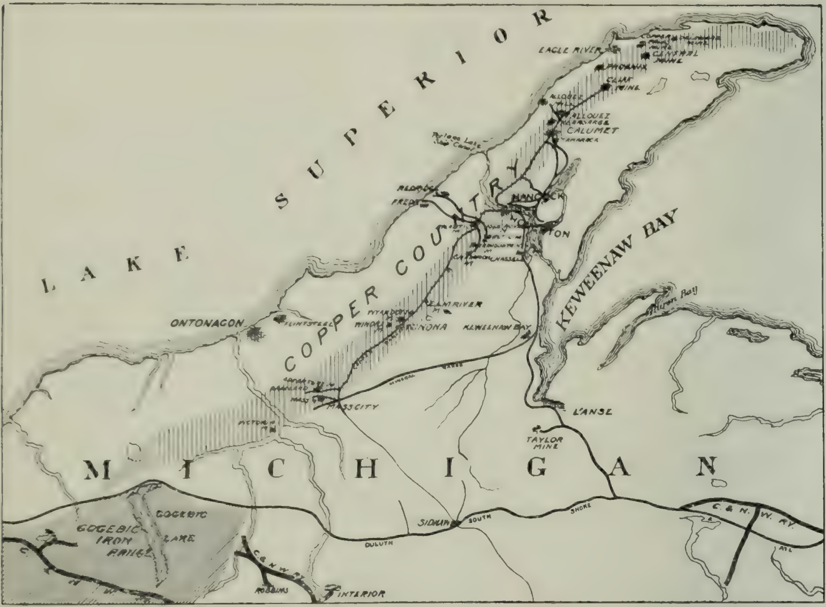

FIG. 1.

at various places as far west as a point on the St. Croix river, south of Duluth. It is not a particularly rough or rocky country. There are outcrops of rocks, but most of the country is covered with from 10 to 200 feet of glacial drift supporting a heavy hardwood forest. This band of mineral bearing formation is composed of hundreds of more or less parallel beds or strata of alternating traps, amygdaloids and conglomerates. The strata, where edges show at the surface, dip to the north under Lake Superior, at angles varying from 25 degrees to 70 degrees from the horizontal. Passing under the lake some of them outcrop again on the other side at Isle Royale, where the dip is to the south, or just the opposite. Geologists will tell you that this mineral belt is bounded on north and south or on top and bottom by sandstones, and that amygdaloids and traps are merely the tops and bottoms of great flows of lava, the tops of the flows being something like slag, quite soft and full of vesicular cavities formed by expanding gas or steam when the material was deposited, and in a plastic condition. These amygdules or almond-shaped cavaties, varying in size from buckshot down, are filled more or less with metallic copper and other substances which have been deposited in them by percolating ground waters. The ground waters are supposed to have gathered the molecules of copper from the adjacent trap rock. There are dozens of these amygdaloid lodes within the three miles of the mineral belt, many of which contain more or less copper in some portion of their length, but only a few have, after development, proved to have sufficient mineral to make a paying mine. Amygdaloid lodes which are developed vary in thickness from 10 feet to 40 feet or more, and are often opened underground for a mile or more in depth and from one to three miles in length.

Besides the amygdaloid copper-bearing lodes there are many beds of conglomerates, which are simply beds of beach gravel cemented together. The great "Calumet & Hecla" and the "Franklin Jr." mines are developed on conglomerate lodes. The copper in this case is found in the interstices between the pebbles. Those interested in the geology of the country will find the subject ably treated in Foster & Whitney's Government report.

A word as to the history of the country may not be out of place. There are in several places "ancient workings" where "mound builders" or some other prehistoric people have made shallow excavations, probably by means of fire and water. The ancient mines were undoubtedly the source of copper knives, fishhooks and other implements so much prized by the archæologists. The government land surveys of this district were made in 1844, and active mining for copper was begun at about the same time, and has continued ever since. Many of the early miners came from the old tin and copper mines of Cornwall, England, and Cornishmen and their descendants are today the leading mining men of the district. In early days the country was reached by steam and sailing boats via the Great Lakes. All copper was shipped out and supplies brought in by boat. Direct connection by rail was not obtained until 1886, twenty years after the great Calumet & Hecla was opened. The price of copper has varied from 60 cents to 10 cents per pound, so that the country has had a succession of booms and times of depression. The great development of electrical machinery within the last ten years, has, of course, greatly stimulated production, and many new mines have been opened. At present the great producers are the Calumet & Hecla, Tamarack, Osceola, Quincy, Champion, Trimountain and Wolverine, besides several small ones. Owing to the fact that United States surveys were made in 1844, ownership and description of mineral lands is by sections, quarter sections, etc., instead of by mining claims located at apex of lode as in western states. This fact has probably saved a great amount of litigation.

Calumet is today the greatest mining camp in the world. It has paid greater dividends, has the deepest shafts, the largest pumps and hoisting engines and the greatest concentrating plants in the mining world.

In attempting now to describe the process of getting out copper in this district I shall for the sake of clearness, make statements which

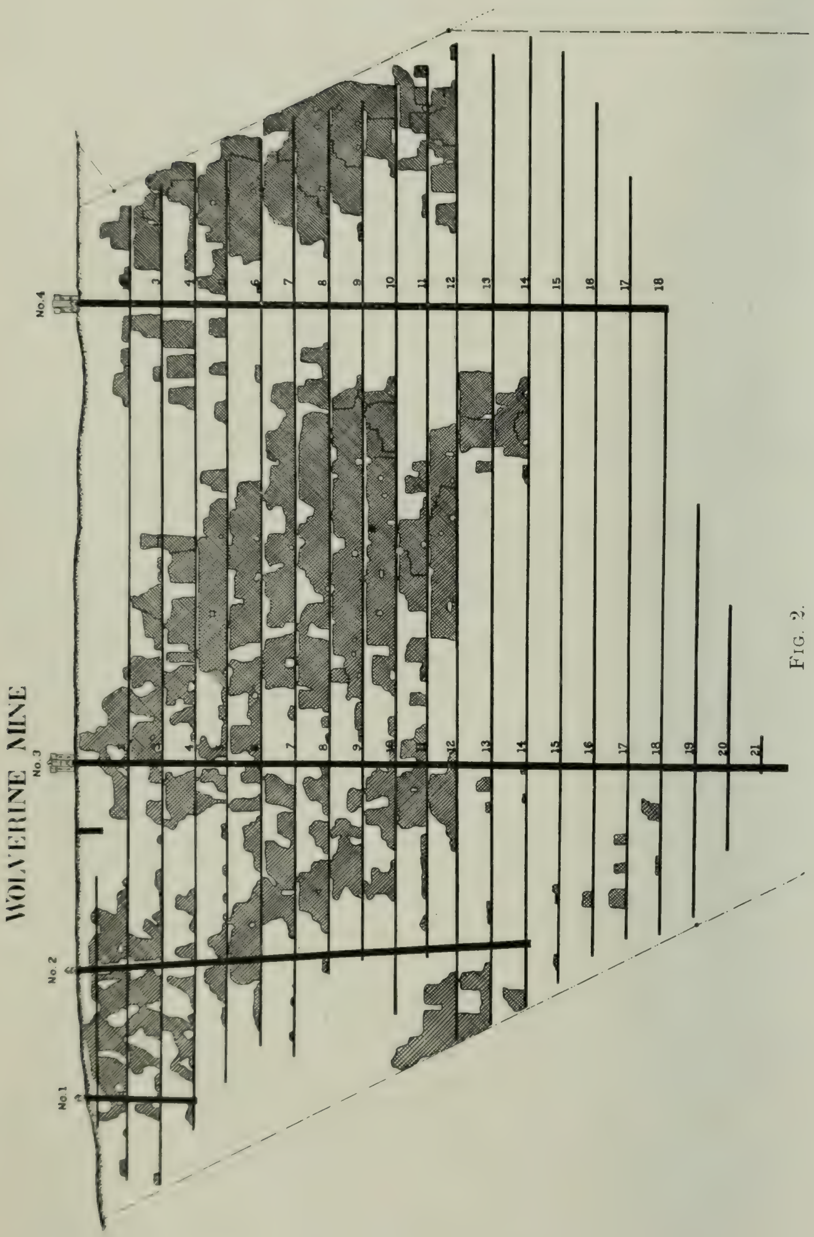
WOLVERINE MINE
No.1
No.2
No.3
No.4

FIG. 2.

are true in general without noting every little exception, and I fear, also, without being able to arrange my facts in logical order. In general then, while copper in Montana and Arizona is found in the shape of an ore, such as a carbonate or sulphide of the metal, whereas the copper of Lake Superior is found in the pure metallic state incorporated in amygdaloids or conglomerates, of which it forms ½ to 4 per cent. A copper lode is usually 12 to 20 feet in thickness and extends from at or near the surface in a broad flat layer of indefinite extent into the earth at an angle or dip from the horizontal of from 25 degrees to 70 degrees. The Calumet & Hecla has a dip of 38 degrees and the Quincy 50 degrees. In opening a lode, shafts are sunk at intervals of 1,000 feet or more apart and follow down the inclination of the lode. Shafts are generally divided into three compartments and measure about 6 feet by 18 feet inside of timbers, giving two compartments for skip tracks of standard gauge and a third compartment for ladders and pipes. This map (Fig. 2) shows the underground workings of the Wolverine mine. The Quincy has shafts 5,400 feet deep in the incline and is equipped to go 7,000 feet. The Calumet & Hecla has a shaft over 6,000 feet deep. At intervals of 100 feet in depth levels or drifts are run out to the right and left. They are, at first, only 6 or 8 feet in width by 7 feet in height. The drifts are connected from shaft to shaft at different levels so as to give ventilation. To begin the work of developing a mine it is necessary to install a temporary equipment. A head frame, an air compressor and hoisting plant of small capacity are put in. If, as the work progresses, the mine shows promise of becoming a profitable producer, dwellings for employes, office buildings, machine, carpenter and blacksmith shops, rock houses and permanent compressor and hoisting plants have to be provided at the mine, and a stamp mill built to separate the copper from the rock. This is the era of development and requires from three to five years of time, and an expenditure of $1,000,000 to $2,000,000 to bring the mine to a point where it can produce 1,000 to 2,000 tons of rock per day. The underground development may, in this time, aggregate 3 to 5 miles of shafts, drifts, winzes, cross cuts, etc. All mining is done with air rock drills of the Rand or Ingersoll-Sargent type, and the miners generally work by contract in parties of four, two by day and two by night. They are paid by the lineal foot of shaft or drift. When the millon or two has been expended and the mine and mill are ready to begin regular production, the drifts are enlarged and "stoping" begins; that is the miners begin at points where there are good showings of copper to work upwards towards the level which is 100 feet above them on the incline. This is called stoping. Stoping is paid for by the cubic fathom. The stoping is conducted at different mines according to different systems, which depend largely on local conditions. I cannot fully describe them here. Suffice it to say that the rock which the miners break down from overhead by the use of dynamite is loaded into tram cars by trammers and pushed by hand or hauled by electric locomotives to the shafts where it is dumped into skips (see Fig. 3,), which

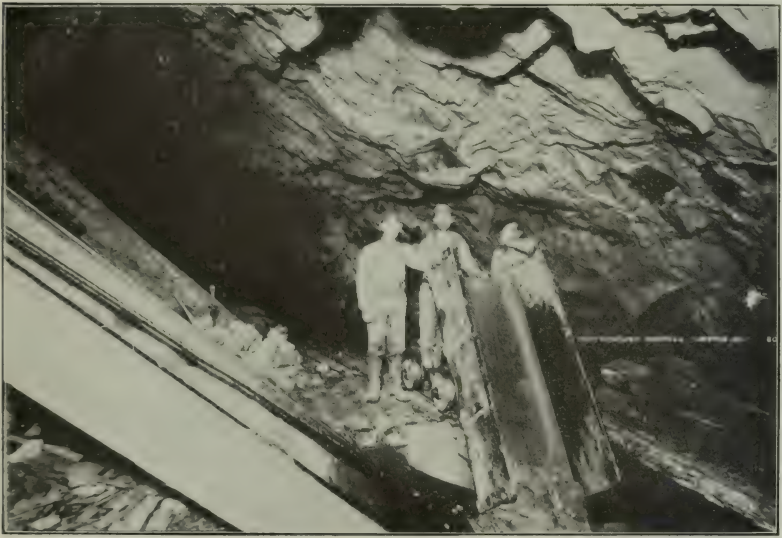

Fig. 3.

hold four to six tons of rock, and are hoisted to the surface or rather into the rock house. In the rock house it is dumped over screen bars which allow the fine pieces of rock to go directly into the rock bins, while the larger pieces are broken in Blake crushers to sizes which will pass through a 4-inch opening. In the rock house waste rock containing no copper is thrown out, and pieces of mass copper from a few pounds in weight to a ton or more, are freed from rock by a steam hammer and sent direct to the smelter.

A notable exception to the general way of opening a mine is found in the great Red Jacket shaft of the Calumet & Hecla mine, and in the five shafts of the Tamarack mine. The Red Jacket shaft is 4,900 feet deep. No. 1 Tamarack is 3,240 feet, No. 2 is 4,143 feet, No. 3 is 4,713 feet, No. 4 is 4,450 feet, and No. 5 is 4,662 feet to lode, now 4,980 feet deep. In this case the Tamarack does not own any of the outcrop of the Calumet lode, but the lode passes under its lands at great depth. One can imagine that it must have required some courage on the part of the projectors to sink the first deep vertical shaft to encounter a lode which might or might not contain copper at the point where intersected. Or later in the history of the mine to start No. 5 shaft, which should require five years of time and a million of money, simply to get down to the lode at a depth of 4,662 feet with the hope of finding rich copper ground. A very valuable paper by W. E. Parnall, Jr., on the sinking of this, the deepest shaft in the world, may be found in the 7th volume of Proceedings of the Lake Superior Mining Institute. In the case of vertical shafts, the shaft intersects the lode at only one point, and the levels above and below this point must be reached by cross-cuts of constantly varying lengths which run from the shaft to the various levels. When the shafts are vertical, the tram cars loaded with rock are hoisted to the surface on cages resembling an ordinary passenger elevator in a tall office building.

We will follow the copper rock a little further and return to the subject of hoisting and hoisting engines later in this paper.

Supposing now that the waste rock and mass copper has been taken out in the rock house, and the stamp rock which constitutes the bulk of the rock hoisted from the mine to be crushed to pass a 4-inch screen, the stamp rock is loaded through chutes into drop-bottom dump ore cars and hauled in trains to the stamp mills located 5, 10 or 20 miles away on the shore of Lake Superior or some inland lake. Stamp mills are located on a lake not only to procure an ample water supply, but also to obtain room to deposit the immense amount of sand which is made by crushing in each mill from 2,000 to 6,000 tons of rock per day. The 6,000 tons of rock handled daily by the Calumet & Hecla mean 5,000 cubic yards of sand per day or 1,500,000 cubic yards per year. Its disposal, therefore, becomes an important problem. At the stamp mill the copper rock is dumped from ore cars into large elevated bins from which it flows in a continuous stream by gravity into the mortars of the steam stamps. Water is admitted to the mortar at the same time and the rock is pulverized by blows from the steam hammer into particles small enough to splash through the perforated screens which surround the mortar. The size of these perforations varies from $\frac{3}{16}$-inch diameter to $\frac{5}{8}$-inch diameter. Each stamp mill will reduce to powder and sand about 500 tons of hard copper rock per day. About 4,000,000 gallons of water per day are required for each stamp head. The water and sand carrying particles of copper flow through separator boxes. The heavy particles of copper seek the bottom of the stream and are diverted from the main stream by adjustable valves. This portion of the flow containing most of the copper and some rock particle is then passed over a series of jigs where by a gentle pulsing action produced by plungers, the copper settles on wire sieves and the rock particles pass over into the waste launder. The finer grades of copper are removed from the main stream which leaves the separator boxes by means of huge round slime tables or by oscillating "Wilfley" tables. The principle in all these washing or concentrating machines is that the heavy particles of copper settle to the bottom on being agitated, while the sand, having less specifiic gravity, is washed away by the flowing water. The waste launders carry the sand and water several hundred feet to the lake where it is dumped.

The 1, 2 or 3 per cent of "mineral," which is the name applied to the product of the stamp mill, is next shipped to the smelters, usually only a few miles away. At the smelter this mineral, now 60 to 80 per cent pure copper in the shape of small grains, together with the solid chunks of mass copper from the rock houses, is reduced in reverberatory and cupola furnaces. The principal flux used is limestone. During the process of refining, green poles are thrust into the molten metal. This process is called "poling" and tends to bring impurities to the surface where they are run off as slag. When the refining has been completed the molten metal is dipped from the furnaces and cast into ingot, cakes and wire bars as may be required. Copper for wire bars and for cartridges must be of very great purity, tensile strength and conductivity. Copper from the Calumet & Hecla, Osceola, Quincy and Wolverine mines is particularly adapted for wire for electrical purposes. Lake copper is usually quoted ¼ cent per pound higher in the eastern markets than the electrolytic brands from the west. Western brands go largely into copper sheets, tubes, brass castings, bronzes, alloys, coinage, etc. There is a wire mill in our district from which quantities of wire of all sizes are shipped direct to consumers. Copper for electrical purposes is refined until it contains less than $\frac{1}{10}$ of 1 per cent of impurities.

It may be conceived that for a single mine to break out and hoist from a mile below the earth's surface a daily product of sufficient rock to fill a train of heavy ore cars a mile and a half in length, and to transport the 7,000 tons of rock to stamp mills, to pulverize the same to fine sand by steam hammers, and to separate the copper therefrom, must require the expenditure of considerable energy, and that problems of great engineering interest must have been met and solved during the development of the business to its present proportions. There are now employed at the Calumet & Hecla 5,000 men; at the Tamarack 1,500; at the Osceola 600; at the Quincy 1,000, and fewer at the smaller mines. The aggregate number of employes in Houghton County is about 14,000. The yearly product is about 200,000,000 pounds of copper, of which the Calumet & Hecla produces 90,000,000. Having given a crude description of the general process of producing copper, I will now call attention to a variety of accomplished facts which may be of some engineering interest. In the first place, taking a trip to the bottom of a mine on the incline track or down a vertical shaft, is not without a tinge of excitement to the inexperienced traveler. Arriving at one of the bottom levels, however, you find yourself in a dry and comfortable tunnel, which you can explore without inconvenience. The temperature is about 85 degrees Fahrenheit and increases 1 degree for each 112 feet in depth. You note how rock is broken from the stopes by miners, loaded into tram cars, pushed or hauled to the shaft and dumped into skips, which run in balance on parallel tracks; that is, the empty car goes down while the loaded one goes up. One cable winds on the under side of the winding drum, while the opposite one unwinds from the upper side, and vice versa. You are told that the skips are hauled up at the rate of 40 to 50 miles per hour and you hope your car will travel a little slower, and wonder whether the 1¼-inch cable will break or the car jump the track while you are going to the surface. Arriving at the surface safely you naturally want to take another look at the hoisting engine which operates the skip, and find that the drum on which the cables are wound is 26 feet in diameter and 16 feet long, and that it is turned 40 revolutions per minute by two 48x84-foot engines attached directly to cranks at each end of a 16-inch shaft upon which the great drum is mounted. Brakes and reversing

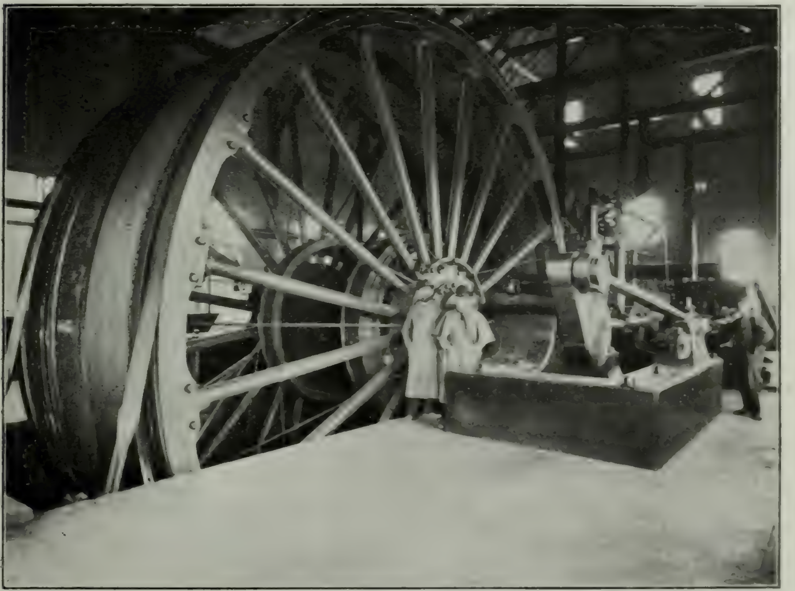

FIG. 4.

gear are all operated by steam. One man has perfect control of the entire machine and obeys signals conveyed to him by bell wire from the mine. A description of the first great Quincy hoist may be found in *Engineering News* of April 18, 1895. Its nominal horse-power is 2,500. Should you go down the 5,000-foot vertical shaft, known as Tamarack No. 5, you would learn some new facts of interest. When the shaft was completed about two years ago, and it became necessary to hang plumb lines in the shaft from which to start the underground surveys, fine steel piano wires and 48-pound bobs were used. The wires stretched several feet but were adjusted to length. They did not come to rest readily, so a vessel of water was placed underneath for the bob to swing in. When this was done it was found that owing to the buoyancy of the water a new adjustment had to be made. On coming to rest, or nearly so, it was found that the wires were 1 inch or so farther apart at the bottom than at the top of the shaft. When this fact became public a number of scientific gentlemen began to construct theories of the attraction of gravity and magnetic currents to account for the phenomenon. After some months of very thorough investigation by President McNair of the Michigan College of Mines, the fact was revealed that the divergence of the wires was caused by air currents in the shaft and not by gravity or magnetic currents. Another curious fact was also brought out by President McNair. He suspended a polished steel ball 2 inches in diameter at the top of the shaft by a thread. A man was stationed in a safe place at the bottom with a telephone and a stop watch. The thread was burned off and the man below notified at the same instant. They wanted to find out how long it would take the ball to fall to the bottom. The man below waited but heard nothing whatever of the ball. It never reached bottom. On inquiring President McNair was informed that particles of rock dropped into the shaft at the top seldom reached bottom, but lodged among the timbers with which the shaft is lined. The explanation of this phenomenon is found in the fact that the earth revolves on its axis with a greater velocity at the surface than at a point one mile below.

Those who are curious about this matter may figure it out for themselves.

The experiments with long plumb lines noted above, suggested the making of experiments with pendulums to determine anew the value of (G) the acceleration of gravity. The only suitable instruments for this purpose were owned by the U. S. Government. President McNair succeeded in interesting the officials of the U. S. Coast and Geodetic Survey in the project. The sets of delicate instruments were placed at his disposal and Major Harrod, chief computer of the survey, was at his own request, detailed to assist in the experiments which were carried out two or three months ago. Two stations were erected; one was at the surface and another 4,000 feet below. The stations were connected by telephone and telegraph, and means were devised for determining with great accuracy the differences in times of vibration between half second pendulums at the surface and at the station 4,000 feet below. From the data thus obtained, equations may be written and the value of (G) determined. The results of these tests will be published by the survey some time next year.

Returning now to No. 5 shaft, you learn that the cage is hoisted at the rate of 50 miles per hour, and that it is loaded and unloaded at top and bottom in a very few seconds. If you are underground at the "Plat," or end of the cross-cut next the shaft, and the attendant signals for the cage to stop for you, you are apt to be treated to another surprise in the shape of an object lesson on the elasticity of steel cables. When the hoisting engine stops, the cage dangling at the end of 5,000 feet of 1½-inch cable jumps up and down 5 or 10 feet, giving the gates or supports on which it finally comes to rest some tremendous thumps.

The inexperienced underground visitor is apt to look with considerable apprehension at the great mass of rock over his head and is disposed to make some inquiries about timbering. The Quincy

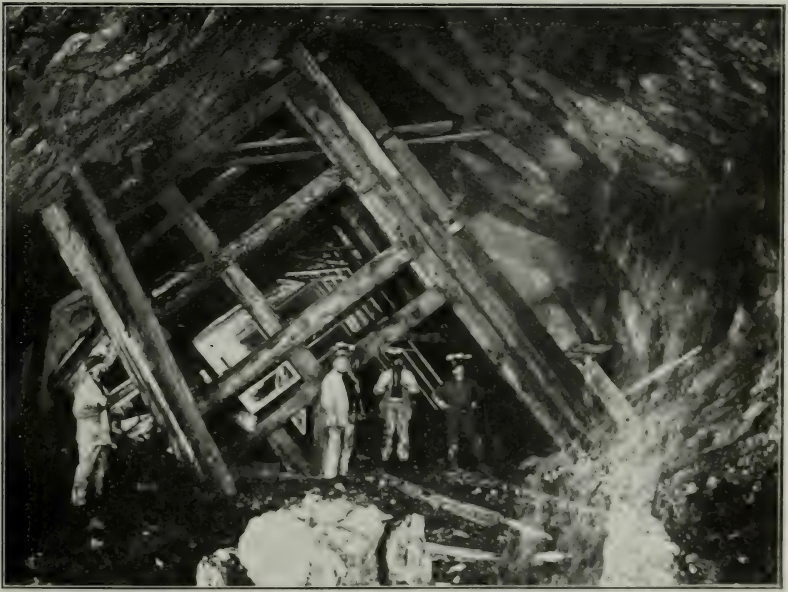

FIG. 5.

and several other mines use but very little timber, except in the shafts, and thousands of feet of unsupported hanging wall may be seen where the copper rock has been removed from stopes. At the Calumet & Hecla and Tamarack, however, a great deal of timber must be used to hold up the hanging wall. The Calumet & Hecla uses something like 30,000,000 feet per year of 12x12 pine, which is framed by machinery and put in in square sets. The Tamarack, which is on the same lode at greater depth, uses round timber stulls, which are pine logs from 12 inches to 4 feet in diameter, and are set up in groups of three or four which stand close together. There are spaces of 8 feet to 10 feet between the groups or batteries of stulls. These timbers are cut to length at surface, lowered into the mine, and set normal to the plane of the lode where they are wedged tightly into place. This timbering must follow the stoping pretty closely to prevent falling of rock. Where a large area on a particular level or a number of adjacent levels is stoped out, and the timbers have become pretty well decayed, the great timbers crush in and rock fills up the excavation. Miners sometimes hasten the process by blasting out some of the supporting timbers. The caving seldom happens unexpectedly. When it does happen suddenly, men working in the vicinity are sometimes thrown violently for some distance by the force of the air current set in motion.

It is, of course, impossible by the use of timber to support the rock from the surface to a depth of 5,000 feet. The pressure would be something like 750,000 pounds per square foot. When caving occurs the rock seems to break back in the hanging to a strong stratum of rock about 150 feet above the copper stratum which is being worked. Pillars are left on both sides of inclined shafts so that they do not suffer injury when caving takes place.

At the Quincy mine there are some very large areas of ground at great depth, which are not timbered, and are supported here and there by pillars of poor rock. Recently two severe shocks, not unlike earthquake shocks, except that they came singly and several weeks apart, have been felt in the vicinity of the Quincy mine. Houses situated 2 or 3 miles from the mine were shaken to an alarming extent. Smaller shocks have frequently occurred in previous years and the common explanation has been that they were caused by "air blasts" in the Quincy mine. In the mine itself, however, but meager effects are observable. Sometimes small masses of rock have fallen from the hanging wall and created a violent current of air. There has been a great deal of mystery about the whole phenomenon, but to my mind it admits of a very simple explanation. The air blast is the effect and not the cause. At the Quincy the rock does not cave in in the same manner as at the Tamarack, but movements which occur may extend to some point near or quite to the surface. There are hundreds of acres dug out at 3,000 to 5,000 feet in depth. Let us suppose for example that five acres in one body have been stoped out at a vertical depth of say 4,000 feet, leaving only comparatively small pillars of solid rock here and there to support the roof of the cavity. If you calculate the weight of rock lying above this area you will find that it amounts to something like 60,000,000 tons. Now if these 60,000,000 tons on our hypothetical five acres, happen to get a little uneasy and shift its position ever so little, say only an inch or less, I think most of us would concede that sufficient energy would be generated to create a serious disturbance which could be felt at a considerable distance. Let us concede then that the power to produce earthquakes is one of the latest achievements of modern man to be recognized. As stated before, the caving at Calumet & Hecla and Tamarack is supposed to extend back only 150 feet or so, and that in falling, the rock being broken up somewhat, occupies more space than it did originally; still when very large areas in the two mines are stoped out and caved in, the rock above the 150-foot stratum may give way even to the surface and cause a shock which might be serious enough to damage buildings all over the city.

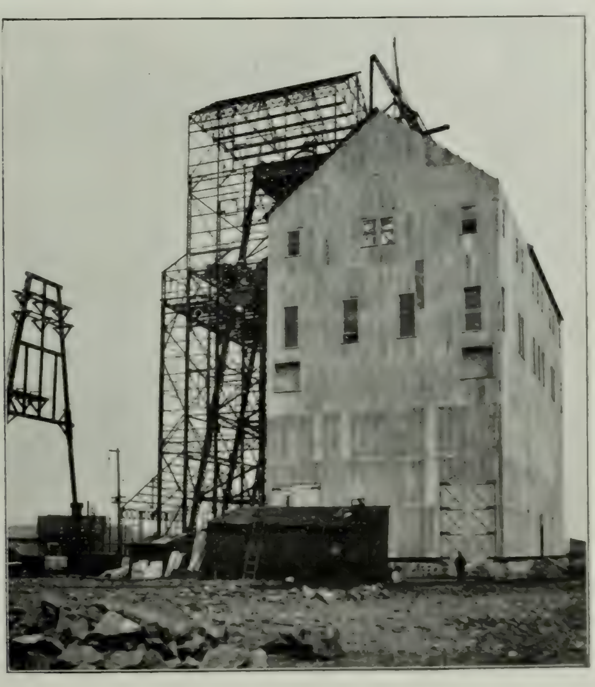

Fig. 6.

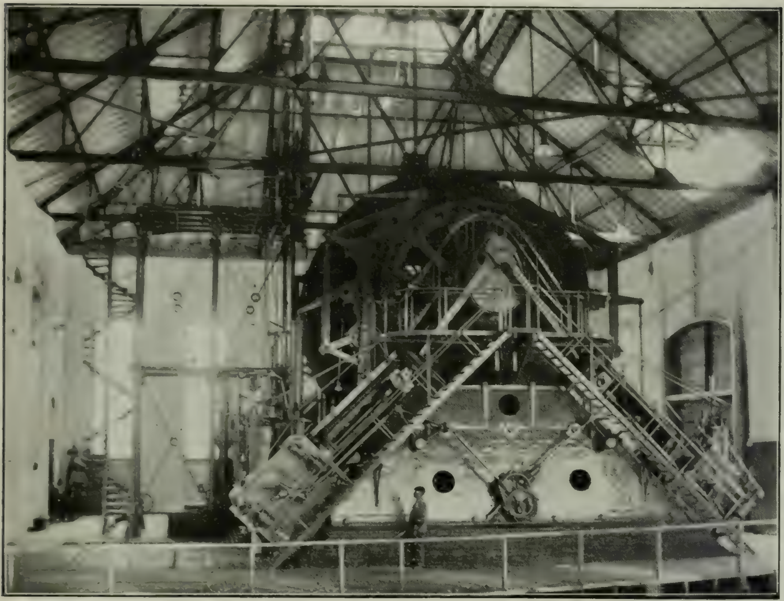

FIG. 7.

This predicting of seismic disturbances is somewhat new business to me, but I simply want to make it clear that settlement of ground above a *deep* mine is a different phenomenon from the caving in of small amounts of earth and rock at an iron mine, or the fissuring or settlement of ground at shallow coal mines. Fig. 6 shows the steel-constructed shaft and rock house of No. 5 Tamarack, where rock is hoisted and crushed before being sent to the stamp mill. One and one-half inch cables from the four hoisting compartments of the shaft lead over the four 12-foot head sheaves, which are at the top of the building, 112 feet from the ground level. Fig. 7 is a picture of the great No. 5 Nordberg hoist of 6,000 horse-power, without doubt the greatest in the world, two of which, installed side by side, are required to operate the four hoisting cables. The winding drum, 25 feet in diameter and 20 feet long and weighing 100 tons, is mounted on a 50-ton shaft and is rotated at 45 to 50 revolutions per minute by four engines, two at each end located as shown. These hoists work in balance and are capable of hoisting six tons of live load from a vertical depth of 6,000 feet. (A full description of this hoist may be found in *Power* of 1899.)

Of late a great deal of attention has been paid to economical steam plants. A number of plants of 1,000 horse-power or more have recently been equipped with condensing machinery, automatic stoker and economizers. The Tamarack can store 150,000 tons of coal at the docks. Coal is brought direct by vessel from Cleveland and other lake ports, and the equipment for unloading and handling coal is of the best.

Hoisting drums are run by simple engines; air compressors have usually triple expansion steam engines, although one of 100 drills' capacity, with quadruple expansion steam engines, is now being installed at the Champion mine. The builders of this compressor confidently expect to set a new record for high steam economy. The various stamp mills, with two exceptions, are supplied with triple expansion steam pumps of 20,000,000 gallons or more per day capacity. The Tamarack has a pump of 40,000,000 gallons capacity; the Calumet & Hecla, one of 65,000,000 gallons capacity pumping against a 60-foot head. This pump is rather larger, I think, than any in use in municipal water works anywhere.

The Baltic and Atlantic mills are supplied with water from a storage reservoir on the Salmon Trout river near where it empties

FIG. 8.

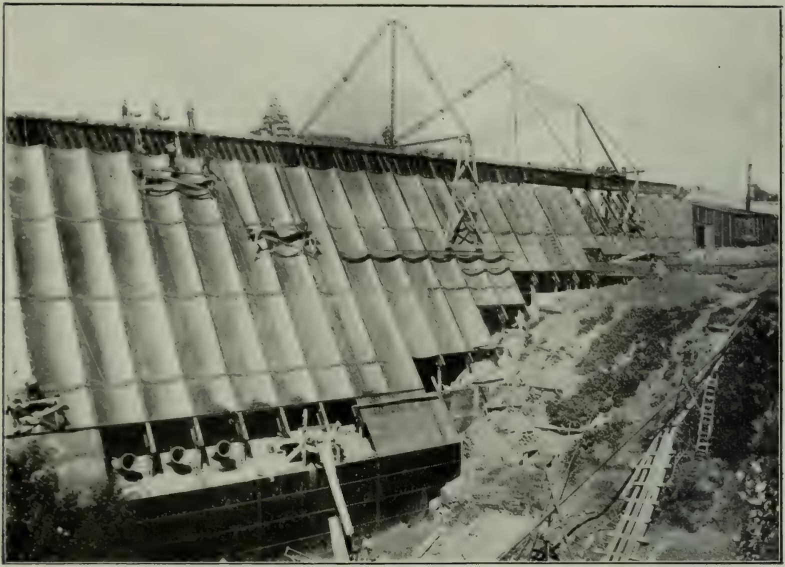

Fig. 9.

into Lake Superior. The river is dammed by a steel and concrete structure, designed by the writer, which is 74 feet in height by 472 feet long. A full description may be found in *Engineering News* of August 15, 1901. This dam is notable in that it is the first steel dam of considerable size to be constructed and particularly on account of the fact that it is a gravity structure; that is its stability against sliding and overturning is calculated and provided for exactly the same as is done in the ordinary masonry dam. These photographs show the concrete base and the inverted V-shaped steel structure which surmounts it. You will note that the upstream face consists of concave plates riveted and caulked, which are supported by bents eight feet center to center. Plates $\frac{3}{16}$-inch thick extend from the bottom of the curved plates over the face of the concrete base and down to bed rock. The dam has been in use about a year and seems to be a highly satisfactory structure. It seems to me that a design of somewhat similar sort should especially commend itself for use in volcanic countries where masonry structures would suffer great damage from earthquakes. Stamp mills are usually placed on the side of a hill near the lake shore at such an elevation that the waste sands and water may flow by gravity through long launders or troughs directly to their point of deposit in the lake. The Calumet & Hecla mill is, however, located on comparatively low ground adjoining Torch

Lake. The mill has already distributed sands over an area of 100 acres or so where the water was originally 100 feet to 120 feet in depth. The refuse sands from crushed rock amounts annually to something like 1,500,000 cubic yards. For several years the sand and water have been elevated about 50 feet by two great sand wheels. The wheels, 54 feet in diameter, are now being replaced or supplemented by a new wheel 65 feet in diameter and having ten-foot face. On the center line of the periphery are gear teeth of 24-inch face and 4.7-inch pitch. A pinion 37 inches in diameter, with one additional reduction and a 750 horse-power motor drives the great wheel, at about four revolutions a minute. On the inner side of the rim of the wheel are buckets which are filled at the bottom of the wheel with sand and water. As the wheel revolves, sand and water are discharged at the top in launders which run out to the lake.* In the early days miners looked for mass copper and one great mass of 500 tons was found. They paid little attention to stamp copper. The first stamp mills were small crude affairs using a few of the old fashioned Cornish or gravity stamps, such as are now in use in the western gold mines. These were replaced later by Ball steam stamps having at first only a small daily capacity. These have been developed within the last few years by Milwaukee manufacturers to a daily capacity of 500 tons or more of rock. The steam cylinders are now made 20 inches in diameter, using steam at 110 pounds pressure. The piston stamp shaft and wearing shoe weigh about three tons and make 95 to 105 blows per minute. The stamp shaft is attached to the lower end of the piston rod, is 8 inches in diameter and about 9 feet long. Its bottom is fitted with a chilled cast iron wearing shoe about 12 inches wide, 16 inches long, 8 inches thick and weighing perhaps 650 to 700 pounds. In conglomerate rock a stamp shoe is worn out in about three days. In the softer amygdaloid rock they last about three weeks.

As now constructed, the cast iron anvil upon which the rock is broken, weighs from 90 to 120 tons. The anvil and frame of the stamp are supported on a concrete and timber foundation resting on solid rock. This concrete and timber foundation is usually 10 to 15 feet thick and 20 feet square, and has anchor rods built into it. So necessary is it to have a solid foundation for stamps that at the Isle Royale mill where there is a great depth of sand, steel cylinders filled with concrete were sunk 75 feet to solid rock. In the matter of stamp foundations one curious idea seems to have survived an unusually long time. In the early days the iron stamp shafts for gravity stamps were found to break quite often. Experience seemed to show that the metal crystallized when the stamps pounded against anvils resting on solid rock. It therefore became the custom to put in so-called spring timbers, that is heavy wooden beams supported at each end and having the anvil in the center so as to give a resilient support, something like the lap stone on a cobbler's knee. When steam stamps were introduced very heavy spring timbers were put in in the same manner and indeed, some of them are still in use. A little later it became the custom to put in several layers of 12x12 timbers in this foundation directly under the stamp and anvil. In fact, within the last ten years the question of whether it would be safe to put in a solid concrete foundation was warmly argued, and all superintendents of new mills, with the exception of two, put some timber under the anvils of new

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*A description of this wheel, which is worthy of a careful perusal, may be found in Engineering News, Nov. 21, 1901.

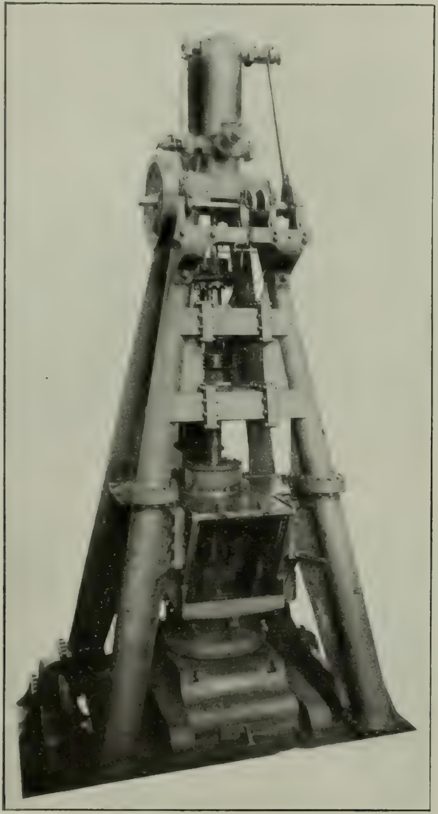


FIG. 10.

stamps which they were installing. At the new Baltic and Wolverine mills solid concrete foundations have, however, been in use several months, proving that modern steel will stand pretty hard usage before suffering destruction through crystallization. I have merely cited these facts as a curious example of how an erroneous idea may persist through forty years, and probably cost money all the time, simply because no one dared sooner refute the accepted theory by actual experiment.

I feel that my paper has been more of a collection of "facts for the curious" than a serious contribution to engineering literature, but if it has given the members of the Western Society of Engineers any clearer idea of the importance and the achievements of our little neck of the woods than that which they previously possessed, my object in presenting it will have been accomplished.

DISCUSSION

President Finley—How is it that the Tamarack company owns ore lands under the Calumet and Hecla mine?

Mr. Jackson—The lode extends under the lands of the Calumet and Hecla, thence under the Tamarack lands. You cannot follow the lode any further than your boundary line. The Calumet company works its lode only as far as its boundary line.

President Finley—Then the Calumet people are working the same lode as the Tamarack.

Mr. Jackson—Exactly the some lode.

Mr. W. E. Williams—I would like to ask if they assume that these lodes extend under the lake?

Mr. Jackson—Yes, they do.

President Finley—Have they ever been worked to any extent under the lake?

Mr. Jackson—The work extends below the lake level about three-quarters ot a mile; not directly under the lake at any point, however.

A Visitor—Are you satisfied that it is not necessary to place timbers under these stamp heads, and can they place foundations directly on concrete blocks without any danger to the mill?

Mr. Jackson—My paper states that the solid concrete foundations of the Baltic and Wolverine mills have been in actual operation for several months, and that they have worked out all right up to date.

Mr. Rice—I suppose the inclination of the strata is as much horizontal as vertical.

Mr. Jackson—Yes.

Mr. Morehouse—Do I understand that the temperature of the No. 5 shaft of the Tamarack mine, down below, is 85 degrees?

Mr. Jackson—To be more accurate, 87 degrees. The temperature does not increase as fast in underground places in this particular section, as commonly accepted. The temperature increases about one degree for each 112 feet in depth.

Mr. Morehouse—Is that the rule for all mines?

Mr. Jackson—Yes, all the mines in that neighborhood.

President Finley—How is the air in those underground places?

Mr. Jackson—The air is very good generally, the system of ventilation being such that there is a down cast shaft and an up cast shaft. The air goes down one shaft and up another. I only know of one case where a fan is used. Ordinarily the air is very good underground.

President Finley—How do they take care of the water?

Mr. Jackson—There is very little water at any of the mines. The Cornish pump is used generally, although there are some electric pumps.

President Finley—Do you know whether the hoists used at the Calumet and Hecla mine are larger than the one at the Homestake mine, Lead City, S. D.?

Mr. Jackson—I think so. I know that those hoists are all very large, compared to any in use; for instance, in the Montana district, Butte, and that neighborhood.

Mr. Reichmann—There must be considerable water in the Atlantic mine.

Mr. Jackson—That is the place where the Cornish pump is in operation. Mine pumps do not receive a great deal of attention in the copper country. In an iron country it is different, on account of the larger volumes of water to be handled.

A Visitor—Do they use steel timbering in any of the mines?

Mr. Jackson—So far it is only in an experimental stage. The United States Steel Corporation, of which Mr. Drake is the chief engineer of mines, has put down two or three shafts, having "sets" made of old rails. That is only an experimental case so far.

Mr. Abbott—Does not the jumping up and down of the car interfere with the loading?

Mr. Jackson—They have to wait until the car comes to rest. Sometimes the car comes to rest quickly and at other times it bounces up and down a number of times. They usually send the men down on a different kind of cage, but they ride up in these cages. When the men are being hoisted they do not run the car so fast. As a rule, in handling men they come to a stop gradually.

President Finley—Have you had any leakages in the dam you refer to, from water along those plates at the junction of the concrete and underlying rock?

Mr. Jackson There are no leakages in the steel work; there is a little leakage at one end through the formation. Under two ends the disintegrated sandstone allows small seepage to take place. That, however, is so little that it does not amount to anything.

Mr. Rice—How is the joint made between the steel plates and the concrete? Do you use anything special?

Mr. Jackson—The side of the steel work is water-tight in itself. The steel work extends from the crest of the dam clear to the bed-rock, to which it is sealed by a rich concrete mortar.

Mr. Rice—How have you protected those plates at the dam side?

Mr. Jackson—Smith's durable metallic paint is use.

Mr. Rice—How long have the plates been in use?

Mr. Jackson—A year so far. The water is supposed to contain few acid impurities, and the plates ought to last a great many years under these conditions. On the under side the plates are always open for inspection.

President Finley—Have you made any comparative cost between the steel and masonry dams?

Mr. Jackson—It was believed, at the time the work was under way, that a steel dam was considerably cheaper than a dam of masonry or entirely concrete. The dam cost a little more than the estimate, however. It is difficult to make the head of a concrete dam entirely impervious.

Mr. Allen—Is there any provision for expansion in the steel work?

Mr. Jackson—Yes, indeed. The curved plates provide for that.

Mr. Allen—Is there no bracing except these curved plates?

Mr. Jackson—The bents are placed in sets of three, leaving one unbraced. Another feature I will mention,—at a depth of 30 or 40 feet under water the temperature changes very little, so that I think a dam could be built, perhaps, without providing for any expansion or contraction. We have water all the time.

Mr. Reichmann—You said the dam did not leak at all. Was it beveled and calked?

Mr. Jackson—The joints are all double riveted, beveled and calked.

Mr. Reichmann—Do you think that was really necessary?

Mr. Jackson—Yes, we thought so.

CXLIV.

DIVERSITY OF PRACTICE IN GENERAL ENGINEERING ON AMERICAN RAILWAYS.

By Archibald A. Schenck, M. W. S. E.

Presented December 17, 1902.

In the development of engineering societies and the helpful discussions at their meetings, one branch of engineering service has received comparatively little attention and slight benefit from these associations. This branch is what is termed General Railway Engineering. It includes reconnaissance, location, right of way matters, grading, tunneling, and masonry. Much of the discussion of most of such topics has been left to the weekly engineering journals. Structural works of each special class have engrossed the bulk of the time of our societies. Particularly have reconnaissance and location been neglected. Special structures are more tangible and visible, and have effect upon the eye and the mind. Reconnaissance and location deal rather with thought than substance, in so far as they avoid needless or poor work. Yet no branch of engineering is of greater importance to our railways financially, both in first cost and in cost of operation. The overlooking of General Engineering in our societies has been partly because of this abstract nature of the topic and partly because, being less pictorial and graphic than building plans, it has failed to interest so generally as a topic of society work. The saving of thousands or hundreds of thousands of dollars by good work in general engineering, is something to be stated rather than depicted. The engineer who makes the saving wins no fame. He gets no advertising by his "minus" work, as does the builder of the great structure. He has benefited merely the company, not himself. Fame and self-advertising are to be gained in spending money and attracting public notice; little is gained in saving money. Because of this, and because of the neglect of general engineering topics, particularly reconnaissance and location, by our societies, general engineering has reached no fixed methods or standards, such as have been developed in branches more distinctly structural. Each engineer has gone his own way, unconscious of any general demand for certain methods or grade of work. The experience of one general engineer has contributed very little in aid of other engineers. It is planned in this paper to touch upon some such topics of engineering which are not very generally discussed, in the hope of contributing a little towards a more settled practice in railway surveys, fieldwork of construction and organization.

The Germans have a form of expression, often used in titles of books and papers, expressive of the fact that such works are not exhaustive treatises, but merely treat of some things concerning the topic in question. Mr. Waddell has happily used the little word "De" in his title, "De Pontibus," with this meaning. The intent of this paper is not to make a full statement of practice on any road, but merely to note some points of difference in engineering practice on American railways, and to mention some of those things upon which special emphasis has been laid on some roads. Any such comparison, based on actual experience extending over many years, must necessarily, for some of the roads named, be somewhat out of date and perhaps no longer the practice in every respect. Minor items are in some cases enlarged upon, because so generally neglected in engineering discussions. The references are chiefly to methods of work, rather than to design of structures.

Describing generally the roads with which the writer has been connected, the leading characteristic feature or aim of the Northern Pacific work is recalled as rapidity of construction; of the West Shore, attempted fine construction; of the Canadian Pacific, solidity and simplicity; of the New York Central (formerly), economy; of the Chicago & North Western, completeness of method; of the Southern Pacific, accuracy; of the Pennsylvania Road, common sense. Such special characteristic mentioned in each case is not to the exclusion of the other traits. In some cases, going from one road to another whose leading aim was widely different has been almost like taking up a new profession, so different have been the methods of work evolved by difference of leading aim.

RECONNAISSANCE.

Classifying by the successive processes of survey and construction, the first item, reconnaissance, is conspicuous on most roads by its absence. A well defined systematic examination and determination, in advance of instrumental survey, of controlling points appears to be undertaken by few roads over any large area. Apart from the general indications furnished by maps, and the suppositions of farmers, woodmen or Indians, but little preliminary information appears to be gathered, and no general determination made of numerous controlling altitudes and positions, before "running the preliminary." In consequence, the running of preliminary lines in actual surveys has been needlessly long and expensive. On one road less than one hundred miles in length, and in a valley where the general course was defined, over six hundred preliminary lines are known to have been run. A liberal determination of positions and double barometer work, or what might be termed detail reconnaissance, however inaccurate for minor variations of altitude, would have eliminated nine-tenths of these instrumental preliminaries. The lack of such detail reconnaissance over broad areas is seen in the huge detours, northward and southward, of the Northern Pacific Road; in the present scenic line of the Canadian Pacific Road west of the summit of the Rockies, and its much admired loop west of the Selkirk summit; in the famous Tehachapi loop of the Southern Pacific Road, where a desperate struggle is made, by turning a complete circle, to gain a very little distance, which a properly established summit cut and slightly different gradient rate would have avoided.

The Alleghenies, with their long, even ranges and nearly level crest lines, presented a fine field for careful detail reconnaissance, there being no deep passes in the crest line so definitely marked as to exclude reconnaissance work along the range. Even many years after construction, the Pennsylvania Road was still examining instrumentally other possible crossings of the range and other summits, such as Three Spring Gap, Emigh's Gap, etc.

I differ from Wellington in the statement that the chief engineer should attend personally to all the reconnaissance. There is what may be termed the preliminary reconnaissance, namely, gathering the facts. A competent subordinate can secure the elevations and positions for numerous possible objective points in advance, besides learning the best means of travel for reaching various parts of the area to be examined. Then the chief can go out, equipped with map well studded with facts, and fill in the conclusions. In going before this preliminary work is done, he simply goes and guesses.

The directors of our railways are in many cases responsible for poor locations of their railway. Two or three years in deciding whether to build, two or three weeks to decide where to build, seems to be the practice frequently. No time is given for systematic examination of large areas in advance of location.

LOCATION.

The method of location of most of our railways can more properly be termed a lack of any method. Each locating engineer has been allowed to take his own course, with no standard for different types of country. On some important roads one long preliminary line has been run through a valley already defining the route. Then the final location has been forced into place, sometimes aided a little by this preliminary, but generally far from it and unaided by it. A series of acrobatic performances in backing off and butting at the ground repeatedly with one curve after another, has been the substitute for systematic locating. If a preliminary has been run, the locating from it has been "from hand to mouth" work, in short sections. The locating engineer would go forth, return and remember "about where he wanted to be" with reference to the preliminary, and calculate his final location from his daily memory. Whether the obstacle be a two foot rise, a stump of unusual diameter, or a cut of hundreds of feet, memory tells not of it. One of our leading transcontinental roads was largely located in its mountain section by this vicious "butting" process. Another along a much greater extent was located by the memory process. It stands today full of hundreds of needless curves, with a loss that capitalized would run into the millions. Its curves about petty obstacles stand as monuments of lack of method, lack of breadth and length of topographical treatment, and with nothing on its almost blank alignment maps to give a reason for its curvatures. Meantime, ruling gradients have been chopped constantly in attempts to rectify errors of position. On other roads in lighter country, locating has merely meant a foot race between locating engineer and right of way agent, as to whether the former could keep ahead of the latter.

Contrasted with this has been the thoroughness of some roads in first grasping fully the topography, and all the topography of importance, of the proposed or possible routes, and placing the same fully on paper, where the broadest treatment could be given and the longest and best possibilities could be noted at one view. Either by contours, or by elevations in small figures at all important ground changes, the face of the country has been transferred to the paper. Line after line of experimental location has been quickly run off with pencil and dividers, the profile of each taken off and platted, its balancing examined and estimating made. A dozen long lines have been examined in an evening, which if run on the ground would have required days or weeks. Long stretches of tangent, long and snugly fitting, but light, curves have been secured, for both of which it paid to run through obstacles which the "memory" or "butting" processes would have curved around. In effect, a thorough, close examination of each and every feature of each possible location is carefully made in advance of running any location instrumentally. As a bridge is carefully planned on paper in all its important details before being laid out on the ground, so is the location of the road planned and studied in advance to best advantage. This was the class of work done by the Pennsylvania Road along the general route adopted for its main line and on most of its branches. The partially constructed South Pennsylvania Road, under the direction of Mr. Oliver W. Barnes, made a fine development of this thorough topographical work of location. Some other roads which have covered a large area of country with a network of preliminaries, have nevertheless failed to gather up the topography from them and place the country systematically and permanently on paper. The company's expenditures have no result in records. The location engineer has placed all the survey results in his own mind only, whereas the company had a right to expect recorded results, that could have been studied by other minds, sometimes perhaps to better purpose.

Such a system of topography and proper location, although generally heretofore used only in rugged country, is really needed even more in light, rolling country, such as that crossed by many of our so-called "prairie lines." In such country a line can be run anywhere, with usable gradients. The best line can only be determined by a broad but close examination of long stretches or areas of country. In no way can this be done except by placing the country, approximately accurately, on paper, and studying the longer possibilities. The Canadian Pacific Road between Winnipeg and Calgary shows evidence of lack of such topographical treatment.

In the details of such topographical work, there appears to be much variety of method and selection of instruments on American railways. The slope instruments, giving angle of surface slopes, with lengths of same measured generally on slope, has been proved to be the most rapid. On the Pennsylvania branches such slopes were taken to a distance out regulated by the proposed gradient rate, the character of the country and the closeness of the preliminary line to the probable location. From three hundred to six hundred feet horizontal, or from twenty-five to fifty feet vertical, were the usual ranges. Beyond this the slopes and distances were taken by eye, and noted on the map in some way distinguishing the eye work from the measured work. The topographer's eye becoming trained, much of the eye work became very accurate, and at times, with trained topographers, was substituted for measured work. The actual profile in most cases coincided very closely with the predicted paper profile, based upon such eye work topography. In such eye work it is requisite that the preliminary be fairly near the probable location, and that the slopes of ground be not too light. Slight changes, purely local, have no importance in deciding the location.

The Allegheny region is an excellent country for the practice of such paper locating. It is not only rugged, but timbered. The butting locator cannot see far enough to butt, and would have to convert his party into a lumbering camp, in clearing for his successive attempts. The "memory" locator is at a heavy disadvantage. A transfer of the country to paper is almost a prerequisite for locating. On one of the slopes to the main summit of the Pennsylvania Road, after many attempts at field locating, the whole country was thrown upon paper and the location decided in Philadelphia.

Entry of the topography upon the map in figures only has been found much better than to elaborate the contours before planning the location. If the figures are made small and distinct and entered in ink, many possible locations can be made in pencil and successively rubbed off after rejection. The elevations being taken at each important change of ground in each cross section, and the sections being taken to suit and develop the ground, the numerous small figures on the map make the best possible representation of the ground. They do not have to be thrown back into figures, as in the case of contours. Intermediate elevations can best be noted from such figures located at the ground changes, and grade elevations and their relation to ground elevation be most readily noted. Such a map closely resembles a coast survey map of soundings. After the location is adopted and inked on the map, the contours can be drawn in (having been interpolated), for the purposes of tracing the finished map. Meantime, there has been no confusion or obscuring of the penciled contours. The contours also can be more accurately determined in the office than in the field under conditions of wet, cold, hurry, etc. No ground need be needlessly contoured on the map, if this contouring is done after the final location has been decided. Figures at ground changes are more reliable than contours. A mapped location may be for long distances in undesirable low cut, where ground change occurs between contours, but this fact not indicated by a map drawn in contours.

The reverse of thorough topographical work and record exists in the case of one of our largest systems of railway, located by the "memory" system, where maps of hundreds of miles of thorough contour work and location of a predecessor were thrown aside and destroyed by the present Chief Engineer.

On some branches of the Pennsylvania Road sheets were taken into the field with these preliminaries and elevations already entered, and locations platted in the field, giving some of the combined advantages of immediate view of the ground together with those of the paper locating. These sheets were of heavy, well sized, best quality printing paper, about 12x16 inches. They were carried in a topographer's board or case made of two very thin boards, closed on three edges, forming a portfolio and drafting board combined, with a hinged cover on one edge; and slung from the shoulder by a strap when not in use. A large paper protractor, a very heavy and accurate specially made rolling parallel ruler, dividers, steppers and scale completed this field outfit. A stump or snow bank furnished a seat. With such appliances a skillful locator has been known quickly to run ahead of others attempting other methods. This platting of the location in the field is not as thorough a method as the office work. It does not permit platting numerous possible locations, taking off their profile, estimating, etc., as in the office, where time can be taken and no field party detained. The longer sweeps of fine possible location are apt to be overlooked. The field platting is suited only to short stretches of difficult country. The locating engineer gets in his best work between 9 p. m. and 2 a. m., undisturbed by his fellow engineers. The preliminary of the day has been platted by the transitman. The leveller has entered on the plat the elevations of center line. The topographer has entered the lateral elevations and notes. Then the map is ready for the locating engineer and his night study. He can determine his location so that when the preliminary line is resumed each morning it can be intelligently pushed ahead, since its relation to proposed location has been determined each evening. Such close methods of study of the location will enable a locating engineer to revise the locations of others, throwing out needless curvature or expense. The writer ventures to mention one of his experiences in such revision on the Canadian Pacific Railway. At the Albert cañon of the Ille-cille-waet River, on the west slope of the Selkirk Range, the location fixed by the prior locating party was low down in the bottom of the rocky cañon, with proposed heavy rock work and tunneling. The situation was a tight one. A very narrow belt or shelf existed about a hundred feet higher up, but the general country was much obscured by dense timber, and any other line was pronounced impossible by the powers that were. A series of preliminaries were run out like threads through the dense woods. The topography was secured from these, and the ground, so to speak, was picked up and put on paper. A line was found saving $237,000, which is the present operated line, and contains nothing remarkable to the eye. The revision was made on snow shoes over eight feet of snow, levels being taken on top of line rods forced down to the ground, and settings of the instruments being made on huge fallen timber.

On branches of the Pennsylvania Road, nearly all the preliminary alignment was taken with the compass, with ball and socket joint; very little was taken with the transit. The balancing of small errors nearly always gave a result closer than any possible platting of the alignment or the location, even with the finest lines penciled in the platting, on scales of 400 feet or 200 feet per inch. The practical results when the location was run in with compass were found as good as if the preliminary alignment had been run in with transit. The saving of time in setting up, lightness in the compass when carried in rough timber, and the saving by setting only at alternate turning points where grade line was ahead, nearly doubled the rate of advance. In one respect the work was safer than transit work unchecked by compass, as no error would be carried beyond its own course, as with transit work, and affect increasingly all subsequent work.

In mapping, the system on some branches of the Pennsylvania Road in former days was to reduce each course throughout to one original north point. A large number of such courses were marked off at one setting of the large paper protractor, thus avoiding the cumulative error often arising from setting the ordinary protractor anew for each course. The same meridian was carried forward, of course, from sheet to sheet. When the platted line reached the edge of a sheet, an additional piece of the printing paper already mentioned was fastened to the preceding sheets with mouth glue. Various shaped pieces were added from time to time, to suit the changing direction, until a map sometimes 20 to 30 feet long was built up. This was then squared up with additional pieces, making an odd looking but very serviceable map. The fine surface of this carefully sized paper permitted the finest lines and points to be used in platting. The writer, under Chief Engineer Leuffer, on one occasion worked up for the Pennsylvania Road 200 square miles of the Alleghenies, testing various alternate gaps in comparison with the present summit above Altoona. President Roberts happened to see the "crazy quilt" rough field map, and in spite of its bountiful annotation of dead midges and mosquitoes, remarked that this was exactly what he wanted, refusing to authorize any finished copy.

ACCURACY REQUIRED.

Accuracy, with the various degrees of the same demanded on various roads, has been an interesting study. The Southern Pacific Company represented one extreme in this quality. Nearly all the work, even of preliminaries, was done with steel tape and two plumb lines. Fifteen hundred miles southward and eastward from Central California, far into the desert, the steel tape and plumb bobs were continuously at work. Where one preliminary crossed another, or the location crossed the preliminary, the proposed crossing, station number and plus, and angle, were calculated in advance, and must conform within an inch or two, and to a minute or thereabouts of angle. All latitudes and departures were calculated for every course both of preliminary and location, the latter including spirals, and recorded in a series of books.

In level work on the Southern Pacific Road, the elevations each 100 feet or other points were not taken on the ground, but on a "pony peg" driven in front of the stake nearly flush with the ground. Every such reading was to hundredths of a foot. Double reading and recording were practiced. The instructions were that an error over a hundredth or two of a foot per mile called for discharge of the employee.

The other extreme as regards accuracy was represented by a road that put accuracy entirely on the basis of utility and cash. It was assumed that no engine would notice a difference of one hundredth of one per cent in gradient, or one fourth of one per cent of the curvature. Therefore it was held that there was no money for the company in revising anything if the levels or chaining were correct within the former limit, or if the curve came to tangent within the latter limit. This seems pretty free work, from an accuracy standpoint. One road noted for attempts at excessive accuracy made most of its benches on heavy plugs where the country was treeless. The soil was adobe, drying out about the plug in summer, enlarging the hole, and lowering the plug and the accuracy considerably.

Tables of the Southern Pacific are submitted showing their requirements in field work and reading. Also some instructions of the Oregon Pacific Road. Also a condensed table of sines and tangents and a formula for radius, which the writer arranged some years ago, and which is convenient for pasting in a note book.

CROSS SECTIONING.

The Southern Pacific Company, in order to bring slopes of excavations to mathematical correctness, puts its engineers over the slopes frequently, setting levels and testing elevations at numerous points on the slope line. In setting stakes for grading, besides slope stakes and center heights, other stakes called height stakes are set. These are at the distance out of outer edge of roadbed, and are furnished in all low fills. They are 2x2-inch oak, the top being at subgrade, or subgrade plus a shrinkage allowance. On curves the lateral elevation is given in the subgrade, causing a varying distance out for edge of roadbed, where the two planes intersect. A compensation for grade is made not only on curve proper, but of varying rate on spiral. At crossings, height stakes are set for top of ramp. The usual vertical curves are used. A combination of lateral slope, compensation for curvature and spiral, vertical curve, and grade crossing, gave an engineer an ample dose of field calculating in setting height stakes and slope stakes.

The writer once, under instructions, staked out many miles of road in open pastures, in advance of contractors whose coming was delayed. The pasture was bristling with stakes long and short, like a forest, forming scratching posts and stumbling blocks for the cattle until well razed to grass level. It is a decidedly difficult operation to drive a "height stake" of any height. These stakes came 12 feet long, in almost car-load lots, and were distributed by team. The handsaw was the most important and active engineering instrument.

The Southern Pacific Road uses a cross section board and two vertical rods very generally in cross section work. The vertical rods are an inch and a quarter square and seven feet long, shod at each end, painted white and graduated in feet and tenths on four sides, zero on two sides for each end. The cross section board is graduated in feet and tenths from one end. A bubble tube is inserted in a groove in top edge, rocking on a round-headed screw, and with a carriage bolt through each end of tube holding the bubble glass. These bolts have a slotted head for screw-driver adjustment of the bubble. The lower ends of the bolts are sunk into the bottom edge of board.

The variations of the pony pegs at center stakes from subgrade are taken off in the office and listed for field use, hundredths of feet being noted. In low fills bottom of cross section board is set as per variation, and slope stake found with outer rod. The writer graduated the boards similar to cross section tapes, with zero at outer edge of roadway, and graduations in one and one-half tenths. Even untrained axmen could stake out correctly many miles of simple embankment in a day. For deep fills or for cuts, even rock cutting, this method can be used with some calculating and practice. It saves much time over cross sectioning with the instrument. The level bubbles are made by the Davis Level and Tool Company, and fitted with the special bolts to order. Two bubbles are more convenient, one near each end of board.

RIGHT OF WAY.

In the method of describing and mapping the lands to be acquired, the widest diversity exists. One extreme was found on the Oregon Pacific Road. The counsel of the company held that the location of the road as run upon the ground was its own monument and reference. No descriptions of courses or boundaries or even of center line were permitted. It was held that any attempt at definition on paper committed the company to something not so certain as the line itself on the ground. Even the distance across the separate ownerships was not given. The amount taken was a strip of a width named, a certain distance on each side of the center line of railway as located and extending across the land in question. This description left the land to go with the line.

In contrast with this, on the Hoosac Tunnel Road the length of every course in all boundaries was calculated and described, including curved boundaries and divergent ones. The course of tangent at the beginning of each curved boundary was stated. The areas were all closely calculated. The description began at one end on center line and followed around all the boundaries to the place of beginning. On the New Jersey Junction Road through Weehawken, Hoboken and Jersey City, similar work was necessary, much of the land being acquired at a cost of one dollar per square foot. In such work the segments of circles for large radii are apt to be in error unless the figures are carried out very far into the decimals. On one road the writer was obliged to divide the land on center line between two companies for about 25 miles. The description of each tract covered sixty pages of closely written foolscap, making the longest deeds known in the state.

COMPUTATION OF EARTHWORK.

The end area method of computation has been found in use on most roads, the prismoidal method on very few roads. The middle areas were computed and entered in the books in red, on the latter roads. The use of the end area method was supported by several arguments. It was held to be fully legalized by custom, as in many similar cases giving quantities not to exact measure. The contractors' habitual prices and bids and profits were held to be based on quantities so determined, and that any reduction in average quantities would merely in time increase prices with no ultimate gain to the companies. Disputing the greater correctness of prismoidal methods to represent quantities was based on topographical reasons. Surfaces were held to be almost invariably convex in cuts, concave under fills, making actual quantities, through this rounding up or down between sections, greater than actual prismoids; and that the excess by end area method met these quantities which the cross sections failed to secure. Other roads introduced actual intermediate sections between the stations or ground change sections, reducing the excesses from end area methods to insignificant errors. Corrections for curvature were rarely made. The writer computed these for one cut of 454,000 yards in 185-foot cut with heavy lateral slope.

ESTIMATES.

On the Southern Pacific Road an unusual method of dealing with quantities of work exists. The engineer parties do no cross-sectioning or measuring for quantities during construction. No quantities are calculated, no record kept of the same. There are no estimates to be made, monthly or final, no contractors to be paid. On the basis of a preliminary estimate made up by the Chief Engineer, the entire work is contracted by the Railway Company to the Pacific Improvement Company for a lump sum. Whether the lump be too large or too small in proportion to the work, or what profit the Improvement Company may make, not even the engineers can tell. The method employed leaves large power and responsibility centered in the Chief Engineer, unchecked by any work of subordinates or others.

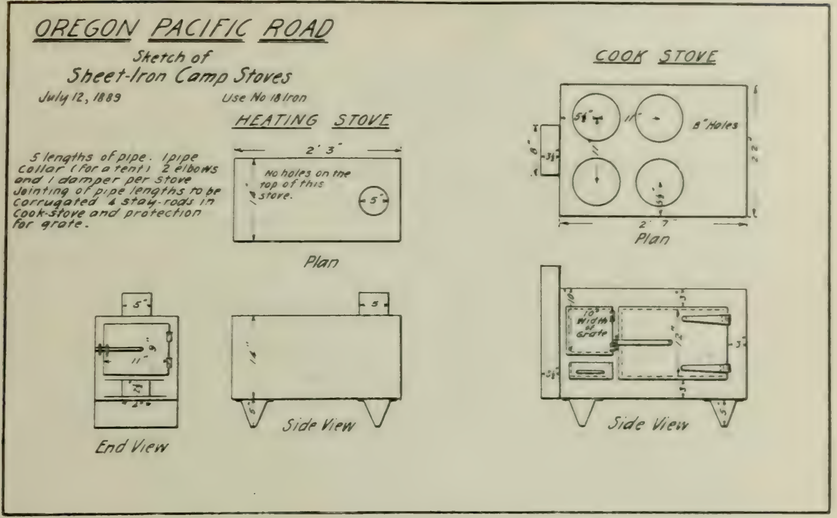
CAMP SUBSISTENCE.

This item of subsistence of engineering parties is a homely topic, giving no special opportunity for scientific discussion or for fame. It is simply a useful topic which has been very generally ignored as beneath the notice of scientific bodies. A great general, even a Napoleon, may very closely consider all details of commissary, but many eminent engineers have felt their calling to be above such details. But the demand is greater upon the engineer than upon the army leader to look after supplies carefully. The subordinates of the engineer can leave at will, or to some extent neglect their work if they be made discontented. New recruits are not always obtainable in the wilderness. The enormous sums paid out yearly by our railways are to secure just one thing, willingness; willingness to work and to remain at work. Nothing, except an overbearing or over-threatening superior, can more quickly neutralize the company's cash expenditures for wages and convert willingness into the reverse, than poor equipment and supplies when the company agrees to furnish them. Their cost (as also that of expense accounts on settled lines of roads) does not aggregate much compared with the total of a pay-roll—but every dollar spent for reasonable subsistence or expenses counts double generally any dollar on the pay-roll. On the Northern Pacific, the O. R. & N. Co., the Oregon Pacific, the Canadian Pacific, and the Southern Pacific Roads, there was a uniform liberality in the furnishing of supplies to the engineer camps. All the cost of camp subsistence, both on construction and location, was paid by the railway company. Equipments were ample and of good quality. Camp cooks were paid from $35 to $50 per month and board. Provisions included not merely necessaries, but such things as canned fruits and vegetables; also fresh meats and vegetables when purchasable. On the Canadian Pacific Road blankets (and buffalo robes formerly) were furnished by the company. The utmost care was taken to provide every article of cooking and camp utensil to insure smooth progress of domestic arrangements, and turn the attention of the engineers away from anxious care for bed and board and towards their proper engineering work. On some roads a special commissary agent was employed for large camps, relieving the engineer of all camp work during movement of camp. On the day of moving the engineering work went on as usual. The party reported in the evening at the new camp, finding the evening meal ready, bedding (of boughs or otherwise) arranged, and the luggage of each man in his tent. On the other hand, many eastern roads when attempting camp subsistence make a wretched failure of it. A large part of the essential outfit is omitted or improperly selected, causing trouble after parties have gone beyond ready reach of articles. Deficient food, poorly cooked and served in slovenly fashion, poor and insufficient tents, bedding, stoves and appliances, cause discontent, poor quality of engineering work, slow progress and frequent desertions.

In very wild countries, such as the Canadian Pacific region, mail facilities were provided by the company. Two visits per week were made by the mail carrier on horseback, even to the most remote camps. Hospitals were established in log cabins each 50 to 75 miles, with a staff of head physician and a local physician at each hospital. The local physicians rode over their territory three or four times per month, and more often when called. A fee of 75 cents per month was collected from each man, medicines being furnished without further charge. The Southern Pacific Company collects 50 cents per month from all employees and has built several excellent hospital buildings.

The lists of camp equipment and supplies annexed to this paper are not intended for reading before the Society, but will doubtless prove useful to those engineers who for the first time are arranging for camp outfitting. These lists were made out by me in 1887 when Chief Engineer of the Oregon Pacific Road, and were used for the field parties, a copy of each for camp outfit and for provisions being furnished the purchasing agent for each construction party of five men going out. Subsequently a copy was, upon request of the Southern Pacific Company, furnished that road. In recent years these lists have been used by some roads and incorporated in their instruction books, but without the information about packages and sizes. This information is almost essential in arranging an exact order for supplies. The camp stoves, of which a design is furnished, were found to be the most satisfactory for camp use, but somewhat lighter metal can be substituted where this is an important object.

The limit of transportation of supplies appears to have been often overlooked, as a determining factor, reducing engineers to very low diet, and contractors and companies to very low treasuries. In a country where food for horses grows there is almost no limit of transportation. Where no feed grows, an absolute limit exists. The pack horse generally is the first means of transportation of supplies in large quantities, in wild countries. Assuming for his food a minimum of 20 pounds per day, and that he can carry 200 pounds, in a round trip of ten days he will eat his pack off his back, delivering nothing. The limit is a time limit, the distance depending on trails and weather. Approximately an average of 50 miles might be assumed as a limit in a country without feed, for delivery of substantial quantities of goods by pack horse. A slow method of storing gradually surplus amounts of feed along the route may extend the distance a little, at large expense. When pack horse limit has been reached, it is necessary to await the advent of the wagon


OREGON PACIFIC ROAD
Sketch of
Sheet-Iron Camp Stoves
July 12, 1889
Use No 18 Iron
HEATING STOVE
5 lengths of pipe. 1 pipe collar (for a tent) 2 elbows and 1 damper per stove Jointing of pipe lengths to be Corrugated 4 stay-rods in Cook-stove and protection for grate.
2' 3"
No holes on the top of this stove.
5"
Plan
End View
Side View
COOK STOVE
8" Holes
2' 7"
Plan
10" Width of Grate
Side View

road. The wagon delivery limit is not exactly in ratio with what a horse can transport on his back or on wheels. The latter require better roads. If a horse can transport on wheels five times the amount he can pack, it is not safe to multiply the 50 mile pack trail by five. I have had four-horse teams making only seven miles in twelve hours, with one ton each, over roads which a pack horse covered in two hours. A multiple of three for wagon limit would be more nearly correct in country raising no feed.

Numerous other points of diversity in practice have heen noted in alignment and referencing, reporting, accounting and distribution, organization; and the tender topics of spirals, bridging, and concrete. The limit of the paper will not permit mention of the marked difference of practice in these items of work.

APPENDIX.

SOUTHERN PACIFIC COMPANY.

(PACIFIC SYSTEM.)

ENGINEERING DEPARTMENT.

INSTRUCTIONS TO TRANSITMEN.

1. See that transit plummet and line are well protected from air currents while being adjusted to the angle point.

2. No instrument station must be in such a position as to prevent the line of sight for Backsights or Foresights striking within two inches or less of the point of the road.

3. Double-center all instrument points, checking each sight back, after setting the point on foresight.

4. No sights are allowed longer than one thousand feet on tangents, or eight hundred feet, or forty-five degrees deflection, on curves.

5. On taper curves, the B. C. or E. C. & C. C.'s of main curve must be put in from each other by one deflection and long chord, and not thro' the intermediate compound curve points.

6. Check all angles by magnetic bearings of all courses, and take true meridian at least once in ten miles, where practicable, in mountainous country, and once in twenty to fifty miles in open plains.

7. A copy of alignment notes will be made out each evening on a traverse sheet, showing true (or assumed) bearings, and magnetic bearings, for use in mapping and for ready detection of errors in notes.

8. All lines in mountainous country will be run with a 50-foot chain. In open country, a 100-foot chain may be used on the tangents and a 50-foot chain on all curves.

9. On location lines, small pegs must be driven to the ground surface, at each chain length, as well as the usual stakes. On preliminary lines, stakes only need be used, except at instrument points.

10. Stakes must be well driven, and fit to stand several years.

11. Chainmen will use hand-levels to determine the difference of height of the ends of the chain, and will use plummets on all rough ground. Chain must be stretched out nearly in line on rough ground, before measuring the short successive distances, so as to use all parts of the chain instead of using one part repeatedly.

12. All instrument stations put in at other points than at end of full chain, must be measured in with steel tape and checked by chain. Where an instrument station is set at other point than at end of full chain, the next full-chain station must be measured from the last one back of the instrument, and not from the instrument point.

13. Chain must be tested once a day at least.

14. All transit books must be paged and fully indexed.

INSTRUCTIONS TO LEVELLERS.

1. Instruments will be kept in adjustment, but dependence for accurate work will be on equal back and foresights, where practicable to take them, or where taken of unequal lengths it must be compensated for in subsequent sights.

2. No sights on turning points are to be more than 300 feet long, and must be shorter where heat in the air or other cause makes results of long sights inaccurate.

3. Leveller must read all sights on turning points himself, to tenths, through the instrument or otherwise, trusting to the rodman only for the hundredths and thousandths of the reading.

4. Rodman will keep a check note-book of turning points.

5. Leveller will check up his turning-point computations by differences of back and foresight sums, and not depend on the rodman's check notes.

6. Intermediate elevations must be checked by difference of elevations and of rod-readings before being platted on profiles.

7. Rod must be swung, back and forth, on all backsights and foresights on turning points to ensure getting the shortest possible reading.

8. Transverse slopes must always be taken at each station of survey and as much oftener as country requires.

9. Take high water elevations, frequently, of all water-courses large or small, search carefully for drift marks and get all available information from old residents.

10. On both preliminary and final surveys, when the line is in the valley of a water-course, large or small, with grade nearly parallel to the flood mark, the leveller will note elevation of water surface (or bottom of water course if dry) at least once each quarter of a mile, and as much oftener as may be necessary, to completely show the grade changes of the water-course. The results will be platted on all profiles, a dash (—) drawn at the proper elevation being used to indicate the water surface or bed of water course, and the usual dotted line being reserved for indicating flood marks.

11. Put in Bench Marks at least every half-mile in valleys, and every one thousand feet in hilly regions. Mark all benches with the letter of the line and the elevation.

12. Bench marks must be turning points and not put in by intermediate sights. Their location must be fully described in field book.

13. When connecting with another line, make full notes of the difference of elevations, and how much higher elevation of bench is by one set of levels than by the other.

14. All level books must be paged and fully indexed.

INSTRUCTIONS WITH REGARD TO NOTE BOOKS.

The notes must be neatly and methodically taken, and must show the time and date for each day's work, and the connection of stations and level bases of different lines. Transit notes will show the beginning and direction of each curve, the calculated and observed bearings of each tangent or straight line, the crossings and directions of the streams, roads and fences, and all other information necessary for platting the alignment of the survey.

When from change of alignment or other cause the original line is shortened or lengthened, the distance lost or gained must be specifically stated and given to the leveler for proper allowance in the grades. Level notes on grade and location lines must show elevations of grade and ground, with cuts and fills.

All note books when complete must be numbered and indexed, showing stations at beginning and ending of each line, and connections of levels and distances of different lines.

Chiefs of parties will be responsible for the enforcement of these rules, and employees not complying either from neglect or incapacity will be discharged.

OREGON PACIFIC RAILROAD.

INSTRUCTIONS FOR INSTRUMENTAL WORK

TRANSIT

Adjustments, including vertical hair, must be tested daily. In each sight at least two-thirds of the rod must be seen; and, if practicable, arrange instrument points so as to see to within twelve inches of the ground on the rod. Double center instrument points. Carry forward the calculated course and check by magnetic, both back-sight and fore-sight, before moving. Avoid producing short sights to long sights if possible. No sight over 1,500 feet or 30 degrees, except in triangulations. In high curvatures, correct sub-chord lengths, when many 50 or 25 foot stations are set by measurements less than 100 feet in length.

ROD

Axeman and others not chaining will watch, as far as possible, longitudinal plumbing of rods. For heights over 4 feet plummet will generally be used. If warped rod must be temporarily used, keep warp in the line from transit, and allow in measurement.

CHAIN

To be tested weekly and after severe work. If possible, no measurements with more than 6 feet plummet line. Axeman will watch whether chain is horizontal. Measure broken stations with continuous chain, and plus stations with the tape.

INSTRUCTIONS FOR INSTRUMENTAL WORK.

LEVEL

Test adjustment daily, including horizontal hair. Test and set from intersection of hairs. Use equal sights wherever possible; otherwise compensate in later settings. Sights generally 300 feet, not more than 400 feet, if possible, and on heated ground or in fog, 200 feet or less. Turning points on "pony" pegs specially set, or on distinct points, marked with red chalk and readily found again. The plus station and distance left or right from center line of every turning point, and character of point, must be carefully noted by eye and recorded. Leveller will read to nearest tenth, call it to rodman and record before setting target. Axeman, if present, will check longitudinal plumbing of rod. After clamping, rod will be slowly swung to front and rear of peg twice and then plumbed for resetting if required. This process will be repeated after resetting and reclamping as often as is necessary. In all setting and in swinging the front of shoe must be on peg. Bench or turning point must be a point; not a flat surface, or a surface rising from peg in any direction. Rodman and leveller will each read and record independently before comparing readings or unclamping rod. For ordinary stations, read surface just in front of stake, setting a "pony" peg down to surface level (where time and material will permit) and one-tenth clear of stake.

Bench marks must be turning points, and fully described, including plus station and distance left or right of line. Benches will be on trees, stumps or permanent objects, and not on hubs, if possible; and set clear of possible grading and generally within clearing limits. Connect with a bench of every connection or adjacent line. Note high water levels of adjacent streams frequently, with descriptions and full data; and high water at crossings of waterways. Mark elevation and letter of line on benches.

INSTRUCTIONS FOR CONSTRUCTION NOTES.

RECORDING

Enter position, name and P. O. address of each man employed. Enter at beginning of each day's work the date; and at the end also the initials of name of each man employed on it. Give dates of Sundays and of days on which other books were used, referring to the same. Index each day's work the same day. The above applies also to cross-section notes.

The calculated courses of each tangent must be entered by the assistant at once on taking charge. Where a revision is made, state from what station of the old line it started, and give the new calculated course of each revision tangent from it; note discrepancy of angle of closure, and state irregular station length, keeping this on a tangent of the revision. Both connection points with original line must be original stationing to avoid confusion. Revisions must be entered in the table the day when made, giving date, station of starting from old line, calculated courses, and variations of angle and distance. Where a double elevation is given to a bench, the new and old elevations must be recorded; and thereafter the letter "F" or "B" must be used on each elevation in the field-book to indicate elevation as carried forward or back. If more than one bench has a double elevation "F^2" and "B^2," etc., must be used. Small discrepancies may be distributed among benches without such lettering, after referring them to the Division Engineer.

In the construction field-book, ink over in black ink (non-copying) such items in each day's work as it is important to preserve permanently, or such as are likely to be referred to and should catch the eye quickly.

PROPORTIONAL TO LESS THAN .00001

DEGREE.	SINE.	TANGENT.	DEGREE.	SINE.	TANGENT.
1°	.0174524	.0174551	49°	.7547096	1.1503684
2°	.0348995	.0349208	49° 30′	.7604060	1.1708496
3°	.0523360	.0524078	50°	.7660444	1.1917536
4°	.0697565	.0699268	50° 30′	.7716246	1.2130970
5°	.0871557	.0874887	51°	.7771460	1.2348972
6°	.1045285	.1051042	51° 30′	.7826082	1.2571723
7°	.1218693	.1227846	52°	.7880108	1.2799416
8°	.1391731	.1405408	52° 30′	.7933533	1.3032254
9°	.1564345	.1583844	53°	.7986355	1.3270449
10°	.1736482	.1763270	53° 30′	.8038569	1.3514224
11°	.1908090	.1943803	54°	.8090170	1.3763819
12°	.2079117	.2125566	54° 30′	.8141155	1.4019483
13°	.2249511	.2308682	55°	.8191520	1.4281480
14°	.2419219	.2493280	55° 20′	.8224751	1.4459801
15°	.2588190	.2679492	55° 40′	.8257703	1.4641147
16°	.2756374	.2867454	56°	.8290376	1.4825610
17°	.2923717	.3057307	56° 20′	.8322768	1.5013282
18°	.3090170	.3249197	56° 40′	.8354878	1.5204261
19°	.3255682	.3443276	57°	.8386706	1.5398650
20°	.3420201	.3639702	57° 20′	.8418249	1.5596552
21°	.3583679	.3838640	57° 40′	.8449508	1.5798079
22°	.3746066	.4040262	58°	.8480481	1.6003345
23°	.3907311	.4244748	58° 20′	.8511167	1.6212469
24°	.4067366	.4452287	58° 40′	.8541564	1.6425576
25°	.4226183	.4663077	59°	.8571673	1.6642795
26°	.4383711	.4877326	59° 20′	.8601491	1.6864261
27°	.4539905	.5095254	59° 40′	.8631019	1.7090116
28°	.4694716	.5317094	60°	.8660254	1.7320508
29°	.4848096	.5543091	60° 10′	.8674762	1.7437453
30°	.5000000	.5773503	60° 20′	.8689196	1.7555590
31°	.5150381	.6008606	60° 30′	.8703557	1.7674940
32°	.5299193	.6248694	60° 40′	.8717844	1.7795524
33°	.5446390	.6494076	60° 50′	.8732058	1.7917362
33° 30′	.5519370	.6618856	61°	.8746197	1.8040478
34°	.5591929	.6745085	61° 10′	.8760263	1.8164892
34° 30′	.5664062	.6872810	61° 20′	.8774254	1.8290628
35°	.5735764	.7002075	61° 30′	.8788171	1.8417709
35° 30′	.5807030	.7132931	61° 40′	.8802014	1.8546159
36°	.5877853	.7265425	61° 50′	.8815782	1.8676003
36° 30′	.5948228	.7399611	62°	.8829476	1.8807265
37°	.6018150	.7535541	62° 10′	.8843095	1.8939971
37° 30′	.6087614	.7673270	62° 20′	.8856639	1.9074147
38°	.6156615	.7812856	62° 30′	.8870108	1.9209821
38° 30′	.6225146	.7954359	62° 40′	.8883503	1.9347020
39°	.6293204	.8097840	62° 50′	.8896822	1.9485772
39° 30′	.6360782	.8243364	63°	.8910065	1.9626105
40°	.6427876	.8390996	63° 10′	.8923234	1.9768050
40° 30′	.6494480	.8540807	63° 20′	.8936326	1.9911637
41°	.6560590	.8692867	63° 30′	.8949344	2.0056897
41° 30′	.6626200	.8847253	63° 40′	.8962285	2.0203862
42°	.6691306	.9004040	63° 50′	.8975151	2.0352565
42° 30′	.6755902	.9163312	64°	.8987940	2.0503038
43°	.6819984	.9325151	64° 10′	.9000654	2.0655318
43° 30′	.6883546	.9489646	64° 20′	.9013292	2.0809438
44°	.6946584	.9656888	64° 30′	.9025853	2.0965436
44° 30′	.7009093	.9826973	64° 40′	.9038338	2.1123348
45°	.7071068	1.0000000	64° 50′	.9050746	2.1283213
45° 30′	.7132504	1.0176074	65°	.9063078	2.1445069
46°	.7193398	1.0355303	65° 10′	.9075333	2.1608958
46° 30′	.7253744	1.0537801	65° 20′	.9087511	2.1774920
47°	.7313537	1.0723687	65° 30′	.9099613	2.1942997
47° 30′	.7372773	1.0913085	65° 40′	.9111637	2.2113234
48°	.7431448	1.1106125	65° 50′	.9123584	2.2285676
48° 30′	.7489557	1.1302944	66°	.9135455	2.2460368

NO 1[illegible] 157-A

$$\text{RADIUS} = \frac{5729.65}{D} + .07\ D.$$

D = degree of curvature. minutes expressed in decimal of degree.

OREGON PACIFIC RAILROAD CONSTRUCTION, 1887

PROVISION OUTFIT

	O. P. R. First Requisition 4 Men and Cook	DAILY RATION			
		O. P. R.	S. P. Co.	N. P. R.	U. S. A.
Flour, 50-lb. sack	200 lbs.	1 1-5 lb.	11-20 lb.	1 lb.	1 1-8 lb.
Oatmeal, 10-lb. bags	30 lbs	1-5 lb.	3-40 lb.		
Cornmeal, 10-lb. bags, 50 lbs. per bu.	10 lbs.		7-20 lb.		
Graham Flour, 25-lb. sacks	10 lbs.	1-20 lb.			
Baking Powder (Price's), ½, 1, 3 and 5-lb. tins	6 lbs.	1-80 lb.	1-60 lb.	1-25 lb.	1-25 lb.
Hops, in bulk	½ lb.				
Baking Soda	1 lb.	1-200 lb.		1-100 lb.	
Yeast Cakes	2 pkgs.				
Fresh Meats	Purchase	1 1-5 lb.	1 1-6 lb.	2 lbs.	1 1-4 lb.
Hams, sacks to order	100 lbs.	1-5 lb.	1-4 lb.	3-4 lb.	3 1-4 lbs.
Bacon, side, 30 to 60 lbs.	1 side	1-50 lb.			
Canned Beef, case, 1 doz., 2-lb.	1 case	1-50 lb.	1-30 lb.		
Lard, 10-lb. tins	20 lbs.	1-20 lb.	1-15 lb.	1-20 lb.	
Butter, in brine, 25 and 50-lb. kegs	50 lbs.	1-5 lb.	1-8 lb.		
Cheese, 24-lb.	24 lbs.	1-15 lb.	1-15 lb.		
Canned Milk, case 4 doz., 1-lb.	1 case	1-10 lb.	1-12 lb,	1-10 lb.	
Coffee, Java. ground, 1, 3 & 5-lb. tins	10 lbs.	1-20 lb.	1-20 lb.	1-13 lb.	8-100 lb.
Tea, Japan, 1 and 5-lb. tins	5 lbs.	1-80 lb.	1-60 lb.	1-125 lb.	1-50 lb.
Sugar, G. C., 30-lb. box	1 box	1-3 lb.	11-40 lb.	2-5 lb.	15-100 lb.
Sugar, crushed, 25-lb. box					
Sugar, granulated, 30-lb. box	1 box				
Salt, 3, 5, 10-lb. sacks, 56 lbs. per bu.	9 lbs.	1-20 lb	1-30 lb.	1-30 lb.	1-25 lb.
Pepper, black, ¼, ½ and 1-lb. tins	¼ lb.	1-600 lb.			
Mustard, ¼, ½ and 1-lb. tins	1 lb.	1-500 lb.			
Cinnamon, ¼, ½ and 1-lb. tins	½ lb.			1-500 lb.	
Nutmeg, ground, ¼, ½ and 1-lb. tins.	¼ lb.	1-500 lb.		1-2000 lb.	
Ginger, ¼, ½ and 1-lb. tins	½ lb.	1-200 lb.			
Mace, ¼, ½ and 1-lb. tins	¼ lb.				
Allspice, ¼, ½ and 1-lb. tins	¼ lb.				
Soap, 20-lb. box.	1 box	1-20 lb.	1-30 lb.	1-25 lb.	1-25 lb.
Coal Oil, 5 gal. can	1 can	1-100	1-150		
Candles, 14-oz., 20-lb. box	1 box	1-10 to 1-40	3-100 lb.	1-80 lb.	15-1,000 lb.
Matches, 1200 per bale	1 bale	2			
Toweling, crash	10 yds.	1-60 yd.			
Extract, lemon, 2-oz. bottles	3 bottls.	1-80 oz.			
Extract, vanilla, 2-oz. bottles	3 bottls.	1-80 oz.			
Syrup, American, 1 and 5-gal. kegs	1 keg	1-200 gal.	1-200 gal.		
Vinegar, 5 gal. keg	1 keg	1-300 gal.	1-120 gal.	3-500 gal.	
Pickles, 5-gal. keg	1 keg	1-300 gal.	1-150 gal.	1-100 gal.	
Rice, 100-lb. sacks	10 lbs.	1-15 lb.	1-15 lb.	1-10 lb.	
White Beans, 60-lb. sacks, 60 lbs. bu.	15 lbs,	1-10 lb.		1-5 lb.	15-100 lb.
Corn Starch	5 lbs.				
Crackers, soda, ⅛, ¼, ½, cases, 60-lb	30 lbs.	1-20 lb.			
Fine Hominy	10 lbs.				
Coarse Hominy	10 lbs.				
Potatoes, 100 to 130-lb. sacks, 60 lbs. per bu.	2 sacks	1 2-5 lb.	1 1-10 lb.	2-5 lb.	
Turnips, 75-lb. sacks	30 lbs.	1-10 lb.			
Onions, 100-lb. sacks, 50 lbs. per bu.	30 lbs.	1-10 lb.	3-20 lb.		
Other fresh Vegetables	Purchase		13-30		
Tomatoes, case 2 doz., 2½-lb. cans	1 case	1-5 lb.	5-6 lb.	1-7 lb.	
Corn, case 2 doz., 2½-lb. cans	1 case	1-10 lb.		1-6 lb.	
Peaches, case 2 doz., 2½-lb. cans	1 case	1-4 lb.		1-7 lb.	
Dried Apples				1-8 lb.	
Evap. Apples, 50-lb. box, 25 lb. per bu.	1 box	1-25 lb.	1-25 lb.		
Evap. Prunes, 50-lb. box	1 box	1-10 lb.	3-100 lb.	1-20 lb.	
Dried Currants	5 lbs.				
Raisins, California, 5 and 20-lb. boxes.	20 lbs.	1-15 lb.	1-60 lb.	1-20 lb.	
Codfish, 30-lb. boxes			1-15 lb.		
Salmon, case 4 doz., 1-lb. cans	1 case	1-15 lb.			
Mackerel, kits 10 and 15-lb., No. 1			1-15 lb.		
Oats, 100 lbs., per 3-bu. sack	2 sacks	20 lbs.			
Hay, 80 to 120-lb. bale (11 lbs. per ration in bale, 4½ lbs. in mess)	1 bale	15 lbs.			

OREGON PACIFIC RAILROAD CONSTRUCTION.

1887.

CAMP OUTFIT.

1 Axe 3½ lbs., handled ; single bitted.
2 Axe handles, extra.
1 Axe, small, 16-inch handle ; extra handle.
2 Axe handles, small, extra.
1 Auger, carpenter's, ⅛-inch, handled.
1 Auger, carpenter's, 1¼-inch, handled.
1 Adze, half head, handled.
1 Adze handle, extra.
1 Awl, scratch, socket, 6-inch.
Axle grease. ½ doz., Dixon.

1 Boiler, tin, 10-quart, round, no bibb, flat bottom.
2 Buckets, covered, tin, 4 quarts.
1 Broiler, wire, extra heavy, retinned, 13½x10, No. 23, H. M. & S.
6 Blankets, pairs, for Company use.
1 Broom, No. 2.
1 Box, packing, large size.
1 Bread board.
1 Bush hook, axe handle eye.

1 Colander, 11x4, agate, No. 306, H. M. & S., feet fast.
1 Cake turner, threaded, 3¼x4½, No. 16, H. M. & S.
4 Candlesticks, common, japaned, 5-inch, No. 2, H. M. & S.
1 Chop tray, oval.
1 Coffee pot, 4-quart, agate, flat bottom, No. 14½, H. M. & S.
1 Coffee mill, box, iron hopper, No. 2, H. M. & S.
4 Canteens, 2-quart, covered and strapped.
1 Chisel, cold, ¾-inch.
1 Crowbar, 12-lb., steel.
8 Cups, drinking, strong, stamped, retinned, 4½x2¼, No. 10, H. M & S.
2 Cups, molasses, 1-pint, japanned.
2 Office chairs, wood seat.

3 Dippers, 1-quart, long handled, pressed, retinned.
1 Dredge box, flour, 4½x2½, No. 3, H. M. & S.
1 Drawing knife, carpenter's, 14-inch.

1 Flesh hook, 20-inch, 3 prongs.
12 Forks, table, iron handles, No. 900, H. M. & S.
2 Files, saw, taper single cut.
1 File, flat, 6-inch.
1 Funnel, tin, ½-pint.
1 Froe, shingling, 12-inch.
1 Frost Breaker.
1 Flooring for 12x16 tent, 4-inch, tongued and grooved.
1 Set Flooring sticks, 4x6 inches, 16 feet, 4 pieces.

1 Grindstone, 63 lbs., diam. in ins. × thickness in inches × .06363 = lbs., say $\frac{1}{18}$ lb. = c. in.
1 Grindstone fixtures.
1 Grass hook.
1 Griddle, granite, 13-inch.
2 Glass, panes, 10x12-inch, American.
2 Glass, sash, 6 panes, 10x12-inch, American.

1 Harness punch, ¼-inch.
1 Hammer, hand drilling, 3-lb., handled.
1 Hinges, pair, riveted, 2-inch, with screws.
2 Hatchets, Ten Eyck shingling, No. 3, one with leather case and belt
2 Lbs. No. 6 horse shoe nails.
1 Bottle H. H. horse liniment.

1 Kettle, retinned, 12-quart, flat bottomed, No. 36, H. M. & S.
12 Knives, iron handled, No. 900, H. M. & S.
1 Knife, cook, 10-inch.
1 Knife, mincing, Enterprise, iron handle, No. 5, H. M. & S.

2 Lanterns, No. 6, for candle and kerosene, with wicks.
1 Ladle, soup, 3-inch, wood handle, No. 633, H. M. & S.
2 Lamps, nickel Rochester desk lamp.
1 Lamp, large, B hinge burner, 6 wicks and chimneys.
1 Lamp shade, tin, 10-inch.

1 Masher, wood.
1 Yd. Muslin, white.
1 Yd. Muslin, black.
1 Mattock, short cutter.
1 Marking pot.
2 Marking pot brushes, Nos. 1 and 3.

10 Lbs. Nails, 20*d* cut = 4-inch, 24 per lb.
10 Lbs. Nails, 10*d* cut = 3-inch, 60 per lb.
5 Lbs. Nails. 6*d* cut = 2-inch, 190 per lb.
5 Lbs. wire Nails, 1¼-inch, No. 14, flat head.
1 Nutmeg grater.
1 Needle, sail maker's, flat seam, 2½-inch.
1 Needle, sack, bent, 4-inch.
Nose bags for pack ponies.

2 Yds. Oil cloth, table.
1 Oil can, for boiled oil, 1-gal.
1 Gal. Oil, boiled, and drier.
1 Oil can, kerosene, 4-quart.
10 Yds. Oil cloth, for mail service and table.

1 Lb. Paint, white lead, ready mixed, in can.
1 Pkg. Lamp black.
¼-Lb. Shellac, prepared.
1 Lb. English Vermillion, ready mixed, in can.
1 Paint brush, marking, No. 1.
1 Paint brush, marking, No. 2.
1 Paint brush, marking, No. 3.
1 Plane, smooth, double irons, 2 inches wide.
1 Plane, jack, double irons, 2 inches wide.
1 Pliers, flat nose, 6-inch.
1 Pot, round, flat bottom, 10-quart, enameled,
2 Pans, drip, 12x17-inch, stamped.
2 Pans, bread, 12x17.
1 Pan, dish, 20-quart.
1 Pan, sauce, granite, covered, flat bottom "Windsor," 12-quart.
8 Pans, 1-pint, straight, flanged, stamped.
12 Pans, 1-quart, straight, flanged, stamped.
8 Pans, 2-quart, straight, flanged, stamped.
2 Pans, 8-quart, straight, flanged, stamped.
2 Pans, pudding, retinned, No. 20, 10x3⅝ inches.
1 Pan, fry, granite, No. 6, 12x2 inches.
14 Plates, dinner, tin, stamped.
4 Plates, dinner, 10-inch, granite.

6	Plates, pie, 10-inch. deep, stamped.
3	Pails, 16-quart, galvanized, flanged.
1	Padlock, with hasps and staples, for chest, No. 5000, H. H. & Co.
1	Pick, surface, No. 3, 5-lb., handled.
1	Pick handle, extra.
1	Pack saddle (Mexican or) sawbuck, oak trees, with cinches, breeching and breast straps.
	Pack saddle blankets, 1 pair per pony.
	Packing lash rope, ½ inch diameter, 40 feet per pony.
	Packing mantuas, 10 oz. duck, 5x8 ft.
.1	Rasp, 10-inch, for pack train use.
1	Rolling pin, wooden, loose handles.
100	Feet Rope, manila, ¼ inch diameter. per lb., 990 ft. coil.
200	Feet Rope, manila, ½ inch diameter. per lb., 990 ft. coil.
200	Feet Rope, manila, ¾ inch diameter. per lb., 990 ft. coil.
2	Doz. Rivets, No. 5, ½-inch.
1	Stove, cast-iron. Buck, 18-inch.
1	Stove, sheet-iron, No. 18, cook, four eight-inch holes and covers; oven for 13x17 inch pans.
6	Stove pipe joints, 5-inch, corrugated joints.
2	Stove pipe elbows, 5-inch, corrugated joints.
1	Stove pipe damper.
2	Stove pipe collars for "A" tents, with wire or McGill fasteners.
2	Stoves, sheet-iron, No. 18, 28-inch box, no top holes and covers.
12	Stove pipe joints, 5-inch, corrugated joints.
4	Stove pipe elbows, 5-inch, corrugated joints.
2	Stove pipe dampers.
2	Stove pipe collars for "A" tent roof, with wire or McGill fasteners.
2	Stoves, Sibley, tent, 30-inch base, 30 inches high, No. 18.
10	Stove pipe joints, 6 to 5-inch, telescopic.
2	Stove pipe dampers, removable.
2	Stove pipe collars for "A" tent roof, with wire or McGill fasteners.
1	Spade, Reed, long handle, back strap, No. 2.
1	Shovel, Reed, long handle, back strap, round point.
1	Skimmer, threaded, flat, retinned, 5-inch, No. 18, H. M. & S.
1	Sieve, flour, wood rim, No. 18 mesh.
6	Sacks, grain, empty.
1	Sledge, 6-lb., cast-steel, handled, double face, one face drawn to a point, 5-inch length.
1	Sledge handle, extra.
1	Screw driver, 4-inch blade.
1	Screw driver, 8-inch blade.
2	Doz. Screws, No. 6, 1¼-inch, and gimlet.
2	Doz. Screws, No. 4, ¾-inch.
1	Scythe, grass, "Champion," beaded.
1	Scythe snath, swing socket loop, brass trimmed.
1	Scythe stone, Indian pond.
1	Strap and buckle for stakes, 1¼ inches wide, 4 feet.
1	Stool, office, high, wooden seat.
1	Spoon, basting, 18-inch, agate.
18	Spoons, tea, tinned iron, solid threaded.
12	Spoons, table, tinned iron, solid threaded.
1	Saw, cross cut, 5-foot, V tooth, with two handles, Disston.
1	Saw, cross cut, hand, 26-inch, with two files.
1	Saw, rip, 22-inch, hand.
1	Pair Saddle bags, medium size, with flap.
1	Saw set, hand, Morrill's No. 1.

1 Saw set, cross cut, Morrill's No. 2.
1 Saw vise, adjustable.
1 Saw, kitchen, 16-inch.
1 Scale beam, 150-lb.
1 Strainer, coffee, wire handle, 3⅛-inch, No. 2, H. M. & S.
1 Stone crock, 8-quart, for butter.

3 Tents, 12. oz. duck, 14x16, 5½-foot walls, pockets in ends and sides, with end ropes and poles, no pins.
(Iron rings and long iron pins).
(Floor cloth.)
(With tent buckles and long straps on door.)
1 Tent fly, 16x20, for 14x16 tent, 8 oz. duck.
Tent storm sheets over door of tent, 14x16, one with buckles and long straps.
1 Tent, 12x14, 4-foot walls, 8 oz. duck, with poles (in place of one above).
1 Tent, 12x14, 4-foot walls, 10 oz. duck, with poles (in place of one above).
1 Table, drawing, 4x6, 3 cleats, in separate boards ; furnish screws and gimlet.
2 Table trestles.
1 Table, dining, 4x6 feet, 3 cleats.
2 Table trestles.
1 Tea pot, agate, lipped, 3-quart, flat bottom, No. 13, H. M. & S.
1 Trap, rat.
1 Trap, mouse.

1 Wash tub, No. 2, painted.
1 Wash boiler.
1 Wash board, zinc.
3 Wash basins, granite, No. 30.
1 Wrench, monkey, 10-inch.
1 Whetstone.
1 Roll wire cloth, 4-foot, for spark protector, No. 18 mesh, No. 25 wire.

OREGON PACIFIC RAILROAD CONSTRUCTION.

1887.

ENGINEERING OUTFIT.

1 Axe, 3½-lb. single-bitted, handled.
1 Axe handle extra.

1 Brush, K. & E. 1301, No. 1.
1 Brush, K. & E. 1301, No. 3.
1 Brush, K. & E. 1301, No. 6.
2 Brushes, K. & E. 1302, No. 6, for renumbering rods.
1 Box for small stationery, 18x30x14 inches deep inside, with drawers and pigeon holes, special pattern ; with lock and two keys and handles.
1 Board, topographical field case, 17x25-inch, sides and space each ¼-inch ; cover with ¼-inch lip and hinges; strap, socket and staff.
1 Board, cross section, level 1x3 inches by 13 feet with adjustable bubbles, 2 extra carriage bolts, $\frac{3}{16}$x2½, head slotted for screw driver, 6 extra nuts and washers.
20 Blanks, authority, pay.
10 Blanks, time sheet, small
10 Blanks, time sheet, large.
30 Blanks, detail, estimate.
10 Blanks, voucher, large.
30 Blanks, voucher, small.
30 Blanks, force report.
[illegible] labor report

20 Blanks, cross section report.
10 Blanks, property report.
10 Blanks, pay roll, engineers.
10 Blanks, pay roll, construction.
5 Blanks, hospital orders.
12 Blanks, identification cards.
12 Blotters, 4x9½.
3 Blotters, 10x12.
2 Books, construction, field, 3½x6½, 400 pages, 5 lines per inch, round corners.
3 Books, memo., field, 4x7, 100 pages, 5 lines per inch, round corners.
1 Book, time, 4⅛x6¾, 24 leaves, H. S. C. No. 303.
1 Book, cross section record, large.
2 Books, cross section field.
2 Books, transit.
3 Books, level.
2 Books, rod.
1 Book, requisition.
1 Book, time check.
2 Books, memo., vest-pocket.
2 Books, topography.
3 Beam compass sticks, 18-inch, 3 feet and 5 feet in length, size as per engineer's order.
1 Book, receipt.

1 Chain, engineers', 100 feet, No. 12 best steel, brazed links and rings, K. & E. No. 6551.
½ cake colors, each Prussian blue, vermillion, yellow ochre, Hooker's Green No. 2, burnt sienna, K. & E. 1100.
1 Chest, stationery, 26x37x18 inches deep inside, with tray 4 inches deep, divided, with one space 6x36, others equal; with heavy hinges, carriage-bolted; lock and 2 keys.
2 lbs. Chalk Fingers, red.
¼ lb. Chalk Fingers, white.
1 Clip board, 9½x12.
1 Clinometer, Davis machinists' No. 1, 6-inch, H. H. & Co., page 157.
2 Crayons, metal workers', for marking rails, D. M. Steward Mfg. Co., Cin., O.
1 Case, map, tin, 4 inches in diameter by 36 inches.
1 Case, map, tin, 3 inches in diameter by 23 inches.

1 Dust brush, oval for drawing table.
1 Diary, pocket, with flap and pocket. 1 page per day, red cover.
1 Drill, ⅛ inch by 6 inches.
1 Drill, ½ inch by 8 inches.
1 Drawing, blue print, O. P. R., roadway diagrams, standard.
1 Drawing, blue print, O. P. R., timber structures, standard.
1 Drawing, blue print, O. P. R., high trestles No. 1, standard.
1 Drawing, blue print, O. P. R., high trestles No. 2, standard.

100 Envelopes, 3⅝x6 inches, manila, H. S. C. No. 6.
50 Envelopes, 4x9 inches, manila, H. S. C.
30 Envelopes, 5x12 inches, manila.
1 Eraser, knife.
1 Eraser, combination pencil and ink, mammoth.
1 Eraser, combination pencil and ink, small.

1 Hand level, Locke's, brass, K. & E. No. 6820.
1 Hammer, hand drilling, 3-lb.

2 bottles Ink, India, Windsor & Newton's.
1 stick Ink, India, K. & E., No. 1200 H.
2 bottles Ink, small, Evan's jet black, or Stafford's Universal or "Caw's."
1 bottle Ink, small, Sanford's carmine.
1 Inkstand, common, 2½x2½ (Banker's ink well).

1 Level, pocket, iron, brass top plate, Davis.
1 Letter scale, Salter's, 4-oz.
1 Level, Y, with cap and ring for tripod.

1 bottle Mucilage, small, Sanford's Royal, with brush.
24 McGill paper fasteners, ½-inch, No. 2 H. S. C.
12 McGill paper fasteners, 1½-inch, No. 6 H. S. C.

2 oz. Nails, ½-inch, trunk.
2 lbs. ¾-inch No. 19 flat-headed wire Nails.
3 lbs. 1½-inch No. 16 flat-headed wire Nails.

1 Oil stone, 15-oz., Deerlick.

Paper, 8x13, best type writer, white, No. 4½, unruled.
10 yds. Paper, Universal, medium, 36-inch, K. & E. No. 33.
5 yds. Paper, Universal, medium, 36-inch, muslin back, K. & E. No. 50.
(10 and 20-yd. rolls.) Paragon, No. 111 N.
2 sheets Paper, tracing, 18x24 inches, Royal, thick, K. & E., No. 63.
Heliograph, prepared, 36-inch, K. & E. No, 79-7, 10-yd. rolls.
Heliograph, unprepared, 36-inch, K. & E. No. 48-7. 50-yd. rolls.
10 yds. Paper, profile, plate A, 20 lines per inch, 9-inch width, green, K. & E. No. 83½, 50-yd rolls.
30 sheets Paper, cross section, 10x10 per inch, blue, K. & E. No 92.
20 sheets Paper, manila wrapping.
10 yds. Paper, detail, manila, 36-inch, K. & E. No. 30.
12 sheets Paper, journal
¼ ream Paper, foolscap, fine ruled, 4½ lines per inch.
⅛ ream Paper, foolscap, broad ruled.
2 pads Paper, letter, headed.
2 pads Paper, memo., headed, 100 sheets per pad.
2 pads Paper, 8x14 inches, buff, fine ruled, 4½ lines per inch, 240 sheets per pad.
6 pads Paper, scratch, manila, 4¼x6¾, 100 sheets, No. 510, H. S. C.
3 pads Paper, scratch, manila, 6x9, 100 sheets.
100 sheets Paper, white, clip, 7x9.
10 sheets Paper, demy, 11¾x16, 1st Prem., double size, Fourdinier, B. Weston, Dalton, Mass.
12 sheets Paper, legal cap.
1 pyramid Pins, No. 4, H. S. C.
2 Protractors, paper, 14-inch, black, K. & E, No. 420.
12 Pencils, lumbermen's, black, Faber.
3 Pencils, lumbermen's, red, Faber.
1 Pencil, indellible, stop gauge, Eagle, No. 865.
1 Pencil, each, Faber's wax crayons, Nos. 4, 13, 28, 34, 69, K. & E., No. 1416½.
1 Pencil, Faber, red.
6 Pencils, 6H, Siberian, Faber, K. & E. No. 1409.
12 Pencils, Faber, No. 5.
24 Pencils, 75 Crown, No. 2, no rubber tips.
2 Pins, adjusting, level and transit.
30 Pens, Pacific Railroad, No. 149.
30 Pens, stub, No. 2, Incandescent Pen Co.
20 Pens, Gillott, No. 303.
3 Penholders, black.
1 Penholder, red
2 Plummets, brass, steel pointed, 6½ oz., H. H. & C., p. 158, No. 5.

1 Rod, Philadelphia Self-Reading, with target, K. & E., No. 6657.
2 Rods, transit, wooden.
2 Rods, transit, steel.
2 Rods, cross section, vertical, 1x1 inch, 7 feet.
1 Rod, combination, transit and level.
1 Reading glass
1 Rubber, Davidson's velvet oblong.

1	Rule, boxwood, 2-foot, 8ths, 10ths and 16ths.
24	Rubber bands, ¼x6, No. 000.
24	Rubber bands, ½x6, No. 000.
50	Rubber bands, $\frac{1}{64}$x3½ inches.
50	Rubber bands, $\frac{1}{64}$x2 inches.
1	Saw, Disston's, back, 14-inch, cross cut.
1	Shears, office, 8-inch blade.
1	Stylograph book, McDonald's, 8½x11 inches, No. 4, 200 pages, with stylograph and carbons.
1	Standard file, No. 6068, H. S. C.
1	sheet Sand-paper, No. ½, for pencils.
1	copy Specifications, graduation and bridging.
8	sheets Strawboard, 17x23 inches.
1	small stick Sealing wax.
1	Straight edge, steel, 3 foot, nickel, one bevel, K. & E. No. 743.
1	Screw driver for level board.

10	yds. Tracing muslin, dull back, Imperial, 36 inch, K. & E. No. 61, 24-yd. rolls.
1	Tape, Excelsior, metallic, 50-foot, tenths, in case, K. & E. No. 601.
1	Tape, Excelsior, steel, 100 feet, tenths, on frame, K. & E. No. 603.
1	Tape wiper.
12	Thumb tacks, German silver, ⅜-inch, K. & E. No. 1022.
6	papers Tacks, 6-oz., cut tinned.
1	paper Tacks, copper, for drawings, 1 M, 1½-oz., Field & Son, Taunton, Mass.
1	ball Twine, ½-lb., No. 18 B, gray elm flax.
1	ball Twine, 1 lb., $\frac{3}{16}$ diameter, flax.
12	Tags, shipping, 2x4-inch.
20	Tape rivets.
1	piece old steel tape for mending tape.
1	Tape repairer.
1	Table, taper.
1	Table, prismoidal, (A. M. W.)
1	Table, track, O. P. R.
1	Transit, with level and clamp to telescope; with cap and ring for tripod.

DISCUSSION.

Prof. W. D. Taylor, M. W. S. E. (University of Wisconsin)—The author has evidently had a very large experience in the engineering field of which he writes. But the writer, although principally interested in the line of engineering work of which the author treats, cannot conceive of any reason why this particular branch of work should be characterized as the field of "General Engineering."

The writer is associated in his work at the University of Wisconsin with other engineers who have charge of the departments of electrical, bridge, sanitary, municipal, hydraulic, mechanical, topographic, and geodetic engineering. And he does not claim that because he has charge of the department of railway engineering that his department is in any wise more representative of general engineering practice than those of his colleagues. And the claim would certainly not be allowed even if made.

The various special departments of engineering keeping step with the industrial development of this country have grown to such an extent, have each developed such a voluminous and complete literature, have each developed a practice so peculiarly its own, that the "General Engineer" may to-day be said to be an impossibility or a hoax. The General Engineer may be an executive officer who has charge of engineers and who does engineering work by the results he gets out of his men. But the General Engineer as a practitioner is, so far as his profession is concerned, on a par with the country quack who prescribes quinine and calomel for all the ills that flesh is heir to.

The author's exposition of the method used to get the leading topographic feature of an *area* of country mapped out so that the best route through it may be decided upon as a connected whole, will commend itself to all who have thoroughly studied to the point of full comprehension the problems of railway location and construction. But the writer cannot agree that the crazy-patch-work-quilt map is a good idea. A more orderly and effective method, a method which permits the records to be reproduced as often as necessary, and which affords better facilities for reference, is to have the country platted on different scale maps. Maps to show the country properly should be made out to at least three scales. The smallest scale map should show the whole project at one view and be of such size, say 22 by 34 inches, that the whole can be spread easily before one sitting at an ordinary desk. Next should be a map more in detail on a scale say of from 2,000 to 600 feet to the inch, according to the roughness of the country, showing the alignment more in detail and the ruling topographic features. It is on this map that the writer prefers to inscribe the ink figures express-ing the altitudes of ruling points rather than to use contours. And lastly the general detail map (which is the only one the author seems to use) should be drawn to a scale of 1 inch to 400 feet in so-called easy prairie country, and even to a scale of 1 inch to 100 feet in rugged mountain country. The second and third map should be worked up in ink on rolls of detail paper that can be conveniently transported, the azimuth of the line being changed as often as may be necessary to keep the line running on the paper. From each set of these maps sheets of uniform size should be traced and numbered and should show the connection from sheet to sheet so that they can be readily laid out on a drawing board in a manner to cover consecutively as large a scope of country as it may be desired to study at any one time.

The writer does not believe that Wellington would have advocated the idea that the chief engineer of a system, say of 8,000 miles of road, should endeavor to make the reconnaissances for the extensions, branch lines, and changes of line, on his system. In Article 19 of his great work he says "the reconnaissance is of all his duties, the one which the *responsible engineer in charge* should personally discharge." The chief engineer of the modern railway system is, more often than otherwise, an executive officer. He has grown up with his system, and he probably has gained his position by reason of conspicuous abilities in lines entirely distinct from railway location and construction. Besides he is often chained down to routine work from which it is wholly impossible to extricate himself long enough to make the complete and systematic examination of a country and its possibilities necessary to determine where lies the one line affording the combination of alignment, gradients, tunnels, bridges, and facilities to secure and conduct traffic, which will make when constructed the best possible investment for the stockholders of his company.

Even the average railway engineer spends a very small per cent of his time in actual railway location. And usually the time which he spends in other railway work such as maintenance, improving an old road bed, yard work, rebuilding structures, or even in building second track or spurs to industries, does little to improve his knowledge of real location work or to improve his efficiency in selecting country, alignments, gradients, and the points best suited to secure traffic. Thus it happens to fall to the lot of a very few to acquire the experience and to have the time to make the special study of the broader economic questions involved, necessary for anything like perfection or even good practice in this line of work. For the construction of their important bridges; for the layout of their important terminals; for the plans of their costly city stations; the railways employ only the very best specialists in each line of work; but let a survey be needed for an important extension and any bright, pushing young man who can stand behind the transit and read off the courses, and who can calculate the quantities excavated by accurate prismoidal formula methods will suffice. Ask the young man to do any one of the other things above and he will at once declare his own inefficiency. But since, given money, men and time enough, any man who has the above qualifications can build a line from any point on the earth's surface to any other point, and since it is possible to make the appearance of a very poorly located line as good as the appearance of a good line, the young man will essay the job, and hope to make good by his zealous work his own deficiencies in experience and grasp of the conditions of the problem.

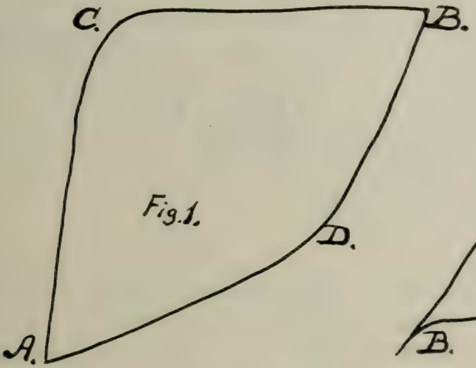
Now it can be easily demonstrated from hundreds of errors that can be pointed out all over the country that the locating or construction engineer of a 100-mile line in difficult country (or at times of even one-tenth this length or less) occupies temporarily a position of greater import and responsibility than any other employe of the company, from the president down. And yet the writer has known the following instance to occur on one of our so-called progressive railway systems: Succeeding a long period of inactivity of railway construction a survey for an important extension in difficult country, whose construction had been decided upon beforehand, was being delayed for lack of an experienced location man. Application was made through the general office for the only man on the system who was thought to have experience enough to do the work. The man had charge of maintenance on one of the divisions. The reply returned was that he could not be spared from more important duties. And the work was done by inferior men.

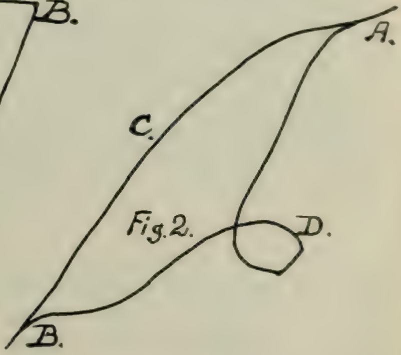
Now the writer does not seek to convey the impression that the principles governing railway location are so abstruse or difficult of comprehension, that only men of overmastering genius can become expert in this work. For the ruling principles in this as in every other industrial science are simple and business like. But though they are so simple they are oftentimes conflicting in their indications, and the failure to give its due weight to any one of them is frequently disastrous to future dividends. And the ability to decide, to give due weight to each governing principle, can be developed only by practice and the systematic study of the economic problems and principles involved.

To illustrate the attention that railway managers and directors so often *do not bestow* upon the fitness of the men who do this work for them, the writer will cite and comment upon some of the location errors that have come under his own observation.

But before doing so he will take occasion to say that his past experience has taught him not to be too ready to criticise the location work of other engineers. The writer was sent to make some improvements on a piece of severely criticised location on a road that had been in operation a quarter of a century. After some weeks of the hardest kind of work in the effort his success in the enterprise was conspicuously absent.

The X & Y Railroad was being constructed from A to B, Fig. 1, a distance of some seventeen miles. After six months' work the route A B C was selected whose profile on the steep mountain side looked like a photograph of the roof and spires of the cathedral at Milan. After a year and an almost incredible number of tens of thousands of dollars had been spent on the construction of the line A B C, it was found that there was a valley route A D B which was shorter, had better curves and gradients, and that it could be constructed for less money than that with which the line A B C could be completed. The road is in operation today via A D B.





This result was due to the veriest stupidity and cupidity.

The line A D B (Fig. 2), 39 miles long, was located and constructed on 1.5 per cent grades, 16 degree curves, and with a loop to get over a 300-foot summit at D. There were no special traffic inducements between A and B. A recent survey has developed the fact that an almost direct line, A C B, along a more or less tortuous water course, is 5 miles shorter, saves the adverse grade, and could have been constructed with 10 degree curves and 1 per cent grades.

This is an example of the work done by an incompetent man really doing the best he knows how. There was a lot of really praiseworthy work done on the details of this construction, but the locator lost sight of future economy in operation as affected by distance, gradient, curvature, and (worst of all) unnecessary amount of rise and fall on ruling grade. It is remarkable how an inexperienced man will put his road across a rolling, swelling country with heavy, unnecessary, adverse grades, rather than place it in the gorge of the creek where so often the only possible location on gentle gradients lies. Such a man will choose undulating country where he will sink his road 40 feet down into long swelling hills if they only look smooth and green on top, rather than encounter the few bristling crags which must be blasted away to secure the narrow foothold necessary on the steep rocky sides of the gorge. Or worse still, he will get permission to use steeper gradients, and will run his road over the tops of the smooth hills and to the bottom of the bounding dales.

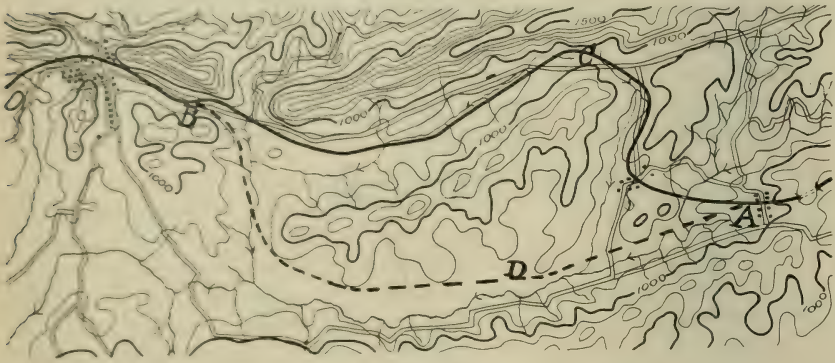


Fig. 3.

Figure 3 is a portion of a map enlarged and traced from a Government geological map, the surveys for which were made since the construction of the road shown. This road has a fairly good coal traffic. Going up to the summit C there is a long, uncompensated 66-foot grade in each direction. The writer had occasion to examine the line A D B for another purpose. There were no obstacles of any kind, just plain sailing and easy grades. The contours shown are 100 feet. When the road was built there was no traffic at C, though now a station is there which could have just as well been at D if the line A D B had been constructed. This is a particularly aggravated case of poor construction and of a kind which frequently occurs. This piece of location was not made by an inexperienced man. He was an old hand at the business. It was not a case of carelessness nor of the kind of incompetence that is easily recognized. This man was a zealous worker. He secured here a remarkably cheap line within the limits of the grades and curves in use. The alignment was fitted to the surface of the ground on the adopted line with great care and some judgment. His duty and view of the matter ended there. He had never learned to study his project as a whole—had never thought out for himself the broad economic questions on which the whole science of railway location depends.

Another one of these old experienced men who has done a lot of location work for at least two of our large railway systems, and who not more than six weeks ago was still at the business, had just completed a location in fairly difficult country and was instructed to go back over his work and see what it would cost to revise his location, reducing his maximum gradients 35 per cent and his maximum degree of curve 37 per cent, both of which had been used with considerable freedom. In due time his report was received to the effect that this decrease in grades and curves would have no material effect on the cost of the road.

Of course the practice of all the roads in respect to the kind of men employed for this work is not vulnerable to attack. Many of them do pay close attention to the matter and employ the most experienced men and the most competent men they can get—for small salaries. The salary of the average locating engineer in this country will rank, even in the sporadic fashion in which he is employed little above that of the locomotive engineer, except that he usually, though not always, has his expenses paid. Such wages may suffice for the bulk of the men who simply collect information for others to use. But there should be connected with every piece of important railway construction at least one man of such training in this special field, and of such breadth of view that the project when worked out by him will assuredly be free of such errors as have been described.

When the railroad companies, as I am glad to say some of them do, pay to such men what they are worth, what their abilities would command in other lines of work, they can feel assured that the layout of their construction work will not be subject to such criticism. And they can feel assured that the money spent in construction has been wisely expended.

Richard Price Morgan, M. W. S. E. (Dwight, Ill.)—The paper of Mr. Schenck upon "Diversity of Practice in General Engineering on American Railways," as a whole, seems to amount to a severe criticism of the railway engineering as practiced in this country; therefore I am tempted to say a few words upon the subject, because whatever the value of his paper may be to the younger members of our fraternity in many details, nevertheless, in some respects, the general impression produced by it will be in a measurable degree erroneous, and perhaps disparaging, and therefore harmful unless neutralized.

In the report of Jefferson Davis, Secretary of War, upon "Explorations for a Railroad Route from the Mississippi River to the

Pacific," embracing 12 quarto volumes of about 600 pages each, there was one important item omitted—the grizzly bear.

Mr. Schenck has omitted a much more important item, which under conditions affecting its selfish instincts is more ruthless than a grizzly, and it has dominated the distinguished civil engineers, probably to their advantage, who have been closely allied since their inception, with the promotion and construction of the railways of this country. This omitted influence, capital, which by careful evolution has accomplished the vast work we now view so complacently, has from the beginning fixed the termini and intermediate points of the separate lines in the system.

The chief engineers have been limited as to cost, and when and where, and indeed how to survey and construct.

Their knowledge of the principles of reconnoissance and location and simple arithmetic was doubtless scientific, and it had to be practical.

The evolution of the trunk lines, which have mostly been constructed tentatively as to cost, character and capacity, is a marvelous study, reflecting in all parts honor upon the engineers.

The Pennsylvania will serve as an excellent illustration in respect to location and grades. As the demands upon it increased and its earning power was felt in its treasury, its capacity as a railroad in respect to alignment, grades, curvature, tracks, power, etc., have been continuously improved, until its wonderful excellence for such a difficult location is a matter of common knowledge with engineers.

During all this period of fifty years and more the distinguished engineers employed by that company have acted strictly within the limits prescribed by the president and directors, else it had been better for them to meet a real grizzly.

These conditions being those which have generally prevailed in railway construction in America and are enforced to-day, and probably ever will be, engineers do not work with a free hand on the side of scientific research and the demonstration of fine economies.

The various statements of Mr. Schenck as to "hundreds of needless curves" on a single line, "chopped gradients," "backing off and butting" a location, etc., give the impression that in his judgment the general engineering of our railways has been unscientific and wasteful, and this result has probably come to his mind because he left out the grizzly bear.

Having been over the lines he speaks of with a view to knowing their character and resources somewhat thoroughly, excepting the Canadian Pacific, and also having quite complete knowledge of the financial history and the construction of the railways of Illinois and adjacent states, and also personal acquaintance with most of the engineers who constructed them, and quite full information of their high standing professionally and their personal worth, I feel that some qualifying remarks ought to be made to more fully develop the purpose of Mr. Schenck's paper, and I have no doubt the members present will freely discuss it.

As to fame, that may arise from the use of a slope board. The occupation is a slippery one at best, and fame also does not always stand on square foundations.

Ferdinand de Lesseps is, according to the books, a famous engineer, even though he did make great blunders in his estimates and other more important things.

Brunel, too, is famous in the books, mainly for his broad gauge railway and for constructing a cradle too weak to sustain the weight of his professional infant, the Great Eastern, which came to an untimely and ignominious end.

Well deserved fame comes to but very few engineers. But many are excellently well qualified, many become distinguished or brilliant; also some are truly very eminent, but they are all necessarily supported by the capital which finds in them professional skill, experience, sound judgment and ability to save enterprise from needless cost and promote its success.

In conclusion I cannot refrain from mentioning the name of the late Capt. James B. Eads, civil engineer, as well worthy a place in the temple of fame.

H. P. Boardman, M. W. S. E. (Milwaukee)—I hesitate to appear to criticise so instructive a paper by an author of such wide experience. I agree with the paper in general and have long wondered that so many miles of railways are located by means of numerous preliminary lines instead of by use of a comprehensive topographical map. As to the methods of taking the topography, the author seems to have entirely omitted to mention the use of the stadia.

Stadia instruments are in use on some railways, but a great many railway engineers are not familiar with their merits. It seems to me that in a large proportion of the location surveys made the stadia method is the best and most economical way of obtaining the topography, and indeed of doing all the field work previous to the actual staking out of the center line.

Where a narrow belt is to be covered, one or two meander lines with a liberal supply of side shots will get more topography in a given time, with fewer men and more accurately, by use of stadia than can be obtained by preliminary lines run with transit, chain and level.

As to accuracy of elevations and distances carried by stadia, if all sights between transit points are read both forward and backward for check, an average instrument man can readily work within $\frac{5}{10}$

foot in elevations and 5 to 10 feet in distance per mile and often much closer than this. This is plenty accurate enough for preliminary work and when the final line is run in and center line stakes set every 100 feet, whatever degree of accuracy is specified can be reached by the transit, level and tape method.

In taking topography by stadia no stakes are required except at transit points and generally but little clearing of lines need be done, for there is no object in running long tangents on a preliminary line for taking topography, and obstacles and thick timber or underbrush can often be avoided without detracting from the information obtained.

In the case cited in the paper where over 600 preliminary lines were run for a location less than 100 miles long, probably less than one-tenth this amount of field work, in taking topography by stadia, would have sufficed for final location if preceded by the kind of reconnaissance suggested by the author.

A fairly rapid reconnoissance could often be made by stadia with only two or three men, using long sights and compass readings, that would give more information than a barometric reconnoissance. In the case referred to, of the revised location made by the author on snow shoes, with instrument settings on huge fallen timber, I think the information could have been obtained much easier by stadia, avoiding all the numerous settings of level and also all chaining in a place where doubtless chaining was difficult.

In regard to laying out different lines on the map I should think it would be easier to grasp the situation if the contours, or at least part of them, were drawn in first, perhaps in colored ink, instead of only inking in the elevation figures. Of course figures marking the elevations of the contours are required in addition to the contours, but I think it easier to grasp elevations by following contour lines with the eye than by "jumping the eye" successively over the spaces between the figures marking elevations.

I should like the author's opinion as to the most suitable scales and also contour intervals to use on these maps for the different kinds of country, such as rolling and mountainous.

As to the office work in connection with plotting stadia notes, the reduction of elevations and connections for distance are very easily and quickly accomplished with a good diagram, such as the one described and illustrated in the Journal of the Western Society of Engineers No. 6, Vol. III, 1898.

W. E. Williams, M. W. S. E.—I do not recall any paper which has been read before this society that is deserving of more consideration by those who are financially interested in the construction of railroads than this paper of Mr. Schenck's. I wish to thank him heartily for what he has said. I give him credit for being one of the best railroad engineers that I have ever known. If I were a Gould or Vanderbilt, or any other large financier interested in railroad construction, I would certainly see that Mr. Schenck had employment.

However, I know that Mr. Schenck will never get the credit or reward that is due him, for this department of engineering has the faults which Mr. Schenck clearly appreciates. In his paper he states that the engineer who makes savings wins no fame, that he gets no advertising for "minus work," as does the builder of a great structure; that fame and self advertising are to be gained by spending money and attracting public notice. Little is gained by saving money.

The engineer who builds a bridge or great structure, has a perpetual visual monument to his credit, that almost every one can see and appreciate, frequently far beyond its merits. And if he has been careless, negligent, or ignorant, it often happens that the structure itself cries out against him by failing or falling down, and hence its builder is in danger of being exposed, not only by the observation of his superiors, but by the structure itself. But the engineer who may spend a good many midnight hours under very trying conditions, in working out a good location for a railroad, is in not much danger of having the merits of his labor discovered and appreciated, or be blamed for his carelessness or ignorance. In order to justly criticise the location of the railroad, requires skill in the art itself and a personal inspection upon the ground, which cannot be had by simply riding over the road in the cars.

Few indeed are the general officers of a railroad company who are capable of judging upon a good location or detecting a bad one by the casual observance of riding over a railroad line.

The officers of a railroad company have diversified ideas about what constitutes a good location. I once worked for a railroad company the president of which insisted that we should so locate the road as to have no cuts, as he had been severely snowbound. The vice-president liked to look upon a long piece of straight line, and insisted that we should have no curves. The general manager, who in his early days had had charge of the locomotives, positively forbade our having any grades—that we must run around every hill. The chairman of the board and the head of the finance committee demanded that the road should cost nothing, so manifestly the locating engineer was in a fair way to be censured at all times and praised at no time.

Many sections of our great railroad systems have suffered severe permanent injuries, as you might say, in their birth, from which it is next to impossible for them to recover, by having had their engineering policy directed by a man who seemed to think that engineering consisted in one particular feature of engineering work, to the neglect of all others. I have frequently observed a vast number of instances where the engineer in his desire to get a long tangent has paid for it dearly in distance, first cost and permanent resistance to traffic.

In one instance, where the location ran along the bank of a large river, at the base of steep bluffs, a six-degree limit of curvature was given the engineer to use when necessity required, but instead, in his desire to get as much tangent as possible, he used that curvature for almost every angle, which occasioned a vast outlay of money a few years later when this line was made a part of a through line.

Too much cannot be said in favor of a proper reconnaissance and a system of topography as set forth by Mr. Schenck's paper, and the memory practice and butting methods cannot be too severely condemned.

Before an engineering party is put into the field to chain and set stakes, the route of the survey should be thoroughly gone over by reconnaissance and mapped out and the elevations taken either by barometer or by the elevations which have been previously obtained from other sources, and the line should be then so calculated and framed up in skeleton, as it were, as to offer the least possible resistance to traffic over it. Not only as to the maximum gradient obtainable, but to avoid reverse grades, as going down hill when a higher elevation is necessary in the same direction farther on.

I was once employed for about four years in mapping out a low grade line of railroad from Chicago to the Red River Valley of the North. It was desired to have a line with the least possible resistance to traffic, and in this work we made a topographical map, as it were, of a large portion of the states of Minnesota, Iowa, Wisconsin and Illinois.

We succeeded in marking out a line and surveying the most of it on a basis of a maximum gradient of fifteen feet to the mile, and strange to say, we secured this with a line as short in mileage as any other line coming from that country. Stranger still, from the highest point reached in the states of Iowa and Minnesota, down to the crossing of the Mississippi River, there was not necessarily a reverse or upgrade, so that the item of elevation which the locomotive was required to lift the traffic upward to the summit arrived at on the entire line was only the one elevation of that summit, and not, as frequently happens, many, many times that elevation—a point which should always be kept in view is any location whatsoever.

I once made a survey for a line which was to cross some broken country in the southern part of the state of Missouri. I went over the route very carefully with a barometer several times before I put the boys to setting stakes and selected the lowest possible maximum gradient that might be obtained, within the limits of the funds of the company; and where this maximum gradient was used I eased it off on the curves, so as to have a uniform resistance. Then there was an opportunity to save money by chopping up the grade line at places that might afterwards be easily remedied with no great expense. I saved all the money that I could. I looked upon this location with a great deal of pride, and thought that I had successfully laid out a railroad such as had never before been attempted in that region. News of my efforts spread to the engineers of the other railroads in the region, and one day I happened to see the chief engineer of the largest neighboring system, and he rather sagely remarked that he never undertook to run a one-per-cent road over a two per-cent country. I pitied him and said nothing. Later, however, my maps and profiles were submitted to a celebrated engineer of this country, for whom I have the greatest respect, and do you know that this man passed over my carefully adjusted lines, with their eased curves up and down the mountain sides, with scarcely a comment at all, and picked out the little places where I had tried to save a few dollars in order to make the construction of the road possible, and pointed out those as evidence of his consultation and engineering skill, and thereby deprived me of all the credit of my other work. So, my friends, it is unsafe for your own welfare to do poor engineering, no matter of how little import or how great the necessity that the enterprise should live at all.

Mr. Schenck's labors in the mountains, wherein he describes the careful study of location under trying conditions of snow and other obstacles, cannot be given too much praise.

The engineer who works out a great bridge structure does so under the most favorable conditions concerning his bodily comfort and surroundings, but the engineer who works out a careful location, a far more difficult problem than the bridge, frequently does so under conditions of mind and body, weather and surroundings that only the slaves that are driven to Siberia under exile can possibly appreciate. The engineer who calculates a bridge structure has before him in easy reach, at his own convenience and his own time, all the data of that class of work that has ever been before attempted, but the engineer who climbs along the side of a mountain, hanging on to the rocks and bushes, and expects almost any moment to be swept away by an avalanche of snow, and whose feet and fingers are freezing, and who has been poorly fed, and has slept with the wolves, is required to weigh and judge, with no loss of time, on conditions which are entirely new of themselves, and are of more moment by far than the bridge, and yet one can live almost an entire lifetime without anybody's knowing that there ever was such a man, and his pay is barely sufficient to take him home, where he can board a part of the year on his wife's relations, provided he should be so fortunate as to have one.

I was told that the president of a great railroad system that stretches over the mountains, not long ago sent to Chicago for five first-class locating engineers for mountain work, to whom he was willing to pay $125.00 to $150.00 per month.

I cannot give Mr. Schenck too much praise for the detailed rules which he has set down for the conduct of this class of work. Every engineer who has anything to do with location should study those rules and enforce them with military discipline. And if he does so, he will not find himself at times confronted with a whole pile of note books which convey no information to him other than that somebody has attempted with a lot of figures to work out some new problems or tables in mathematics.

In the matter of accuracy Mr. Schenck has given us some good points. Common sense must be exercised at all times as to the measure of accuracy required on the measurements and monuments of surveys, consistent with the conditions. I once worked under an engineer who had lived in the city of New York, and who had been trained to take his measurements down to small fractions of an inch, which were necessary in measuring land in the vicinity of Wall Street, and this man insisted that we should take measurements like that in the open prairie country in Nebraska, where, as to values, one lot on Wall Street could be traded for a whole township or more. By this man's rules the railroad company was put to a vast amount of unnecessary expense.

In the matter of right of way Mr. Schenck has brought to light some of the difficulties of land description that the legal department sometimes enforces upon the engineering department in describing the right of way.

The attempt to describe right of way by meets and bounds, giving the direction of all courses, is open to censure, not only as nonsensical, but such a description requires a more skillful surveyor than the ordinary county surveyor (usually obtained) to stake out on the land thus described, while on the other hand the monument of the railroad line itself is more fixed and definite than the ordinary land survey monument.

In the matter of the computation of earthwork he has given us some good hints. It has been the common practice of a good many engineers to require excavation measurements on all classes of earthwork, without regard to the difficulties encountered in measuring the borrow pits.

I recall a case of a large amount of construction in the prairie country of Nebraska and Kansas, where the chief engineer's instructions were severe in the requirement that all of the borrow pits must be measured and in no case the embankment measurement to be taken. However, the boys who did the work carried out his orders in this way: they first calculated the quantity of the embankment made from the borrow pit, and then they measured the top widths of the borrow pits, and calculated the depth that such borrow pits would have to be in order to produce such an embankment, and set that down as the depths of the borrow pits. Thus they got along and saved themselves and the company too the expensive necessity of measuring every little irregularity of prairie borrow pits, even though the chief engineer required it.

Mr. Schenck has furnished us most excellent data in regard to camp subsistence. I once knew an old engineer, a remarkably successful man in so far as his management of men was concerned, and he gave this rule to all of his subordinates who were to have charge of men under them: "No matter what the circumstances are, always try and get your men something to eat when it comes time to eat, for hungry men are like hungry wolves; they want to eat one another up. More fights and unpleasantness are occasioned by the dinner being behind time than for any other one cause." A little money spent in feeding the boys on the survey will give better returns than any other possible railroad investment.

Mr. Schenck's statements about paper location are, I think, likely to mislead us. I think that he intends to depend on paper location only where the country is of such a nature as to cause it to be the only safe way, and that it was not to be used for local or small sections of open and smooth country. I think that the "memory" locator who sometimes can justly be proud of his work is too apt to put the paper locator in the same class with the "paper-collared cuss" that sometimes comes into a flannel-shirted camp. On the other hand, the map man often makes the opposite mistake. The man that is occasionally found on location who needs a compass to tell him the way home on all occasions, stands to the profession in about the same relation as a blot on the paper does to the writing. He should not be there and no rules in engineering practice can be laid down for him.

To be an engineer at all entitled to general practice such as a railroad requires, commands first of all that he be a man of clear perception and observation, who can take, grasp and hold a stretch of scenery and build thereon in his mind the structure desired without necessarily putting it all on paper first. The paper location should not in any instance be entirely dispensed with. As the problem becomes less difficult the paper problems can be made to cover larger areas and the memory given to the detailed sections.

No location, however simple, should be decided without serious reflection, and have for its final decision good substantial reasons that it is the very best obtainable, and not simply that "it is good enough," and comes within the limits of our maxims. The idea of making a line straight between the limiting points and trying to arrive at that with a location is generally a good one, but it has a serious pitfall. Lots of railroad lines that cross the country in general direction comparatively straight on the map, but with short variation of alignment, are longer in miles between terminal points than lines that make wide detours from general direction, but are more straight in detail alignment. I once made a survey for the purpose of saving mileage from the central western part of Minnesota to Chicago, passing south of St. Paul and Minneapolis about fifty miles, which on the state maps appeared to give us a great saving in distance. But when the line was surveyed and we took our survey mileage and compared it with the mileage of the roads passing through St. Paul, we found that the St. Paul route had us beaten a little, which was owing to the crookedness of some narrow valleys that our line had to follow.

An example of this sort of detailed crookedness is found on the St. Louis & San Francisco road in the southwestern part of Missouri, in the region of Springfield. I was told that the engineer who located that line had instructions to follow the summit of a long ridge, which is quite broad and flat generally, but broken a little at some points. This ridge is commonly known as the Ozark Mountains.

The engineer followed his instructions literally, for the road in that portion that I inspected is almost the exact summit of the watershed, causing much needless curvature, loss of distance, increased gradient resistance and expense of excavation. In places where the ridge took upon itself an easy high bump a little off of his direction, he was not content to run by it on comparatively smooth ground, where he could choose his own elevation, but he must run over the top of everything if possible and be supreme in elevation and beautifully sinuous in curvature. One might think by examining that line that that engineer tried to make a continuous monument for a hydrographic line instead of a railroad.

If the stockholders of the road knew what that engineer cost them, they would not "hang him to a telegraph pole," but I fear that they would burn him at the stake.

Just a word about the midnight oil that Mr. Schenck mentions. I understand by this that the valuable results obtained by it come from the fact that in broken, difficult country each new day's work of location is so dependent on the results and discoveries of the last day that no extra day's work can safely be laid out in advance, to permit the head of the party that surplus time in which to work out his problems in the day time. That Mr. Schenck worked nights is much to his credit.

W. C. Armstrong, M. W. S. E.—It is to be regretted that the writer of our paper this evening has attempted to cover so much ground, for many of the numerous subjects covered are of sufficient importance alone to occupy the attention of this Society during an entire session. The paper loses much of its value and force by reason of its diversity in subject matter.

I heartily agree with the writer's statement to the effect that the general problems of railway location and construction have not received the helpful discussions of engineering societies that have been devoted to other branches of engineering. Literature of a high order on these topics is lamentably scarce. Very little of value had been written on the economic principles of location until the subject was taken up and elaborated by Mr. Wellington.

The diversity of methods mentioned by Mr. Schenck, in so far as they relate to the details of work, is generally the result of individual opinions and ideas; and uniformity in these matters, however much the various methods may be discussed, can only be secured at the sacrifice of individuality. I do not believe that a rigid uniformity in detail of method is desirable. It should make no difference to a chief engineer whether a line is located as a map location, or by Mr. Schenck's so-called "butting" process, providing the location was equally expeditious and good. It makes no difference to the bridge engineer whether a stress sheet is worked up graphically or analytically, providing the results are as readily and correctly obtained. It is the results which concern us, not the method by which the results are obtained. I think in any engineering organization, general instructions in methods of work should be reduced to the minimum consistent with the efficiency of the organization, leaving to the individual the greatest possible freedom in the employment of methods. General instructions should deal with the large problems of railway engineering: the extent and scope of the reconnaissance; the preliminary line, its purpose and scope; the final location, its ruling gradients and elements of length, rise and fall and curvature; the construction, its general character, type of structures, etc. A certain uniformity in practice within each railway system can thus be attained, but a more general uniformity can only be gained through the broader knowledge for which we are striving and for which such societies as this are organized.

I only wish to refer in detail to a few of the points discussed in this paper, some in which I agree with the writer's opinion, others in which I do not.

I agree with him on the value he places on a well executed reconnoissance and in his statement that too little attention is generally paid to this means of collecting data in advance of the instrumental survey. An experienced locating engineer with a barometer and pocket compass can determine within a reasonable approximation all the salient features of the country, the altitudes to be overcome, the gradients necessary, the probable maximum and total curvature, and with a little extra time spent in detailed examination, can make a fairly accurate estimate of the quantities of grading and bridging.

One reason, I think, why a more thorough reconnoissance is not generally made is that the railway company does not want to "show its hand," so to speak, before it is ready for business. This reason, however, only applies in country that is tributary to competitive lines. While I do not question the wisdom of secrecy in the inception of many railway projects, the method employed in maintaining it fall as a handicap on the locating engineer, who is not only deprived of the benefits of a careful reconnoissance but is not allowed sufficient time to work out the best results.

The author of our paper brings up the old question of map location against field location, claiming the great superiority of the former, with which opinion I am compelled by conviction to disagree. I do not want it understood, however, that I am advocating the latter to the disparagement of the former. Each method has its value, and the best results are only obtained by a judicious combination of the two. An ideal method of location should observe the following order of procedure: A preliminary line should be run through to some objective or controlling point. All possible alternatives not eliminated by the reconnoissance should also be run. These lines should be carefully platted on the same map, if not too widely divergent, properly connected at their points of juncture. Topography enough should be shown to represent the salient features of the country a few hundred feet either side of the preliminary line, and fix all controlling points in the location. Each preliminary line should be fitted to the country it traverses, with a reasonable degree of accuracy in order that it may serve as a working base for the location that is to follow. Random preliminaries are but little better than reconnoissances. No hard and fast rules can be given for the correspondence between the preliminary and the following location. It depends on the character of the country, and the judgment of the engineer is supreme. Ordinarily, a preliminary line loses much of its value as a working base if it is necessary to depart more than five hundred feet from it even in what is generally termed easy country.

Having platted the various preliminary lines, the general alignment can be studied from the map, comparative estimates made from the profiles of the preliminary surveys and if these surveys have been made with the proper attention to detail, practically all the questions entering into the determination of the general route of location can be determined. It then remains for the engineer to put this location on the ground. In doing so, he may be aided to a certain extent by first projecting his lines on the map, and generally he will find this a valuable aid; but the final adjustment, the proper fitting of the line to the contour of the ground, is a problem to be solved in the field with the transit, level and tape, aided by the skillful eye of the experienced engineer, and not a problem for the office, to be solved with protractor and dividers.

I am not speaking without authority; in my own experience I have tried both methods. I have also discussed the problem with a great many practical locating engineers whose opinions are to be regarded as of the highest importance, and I have found the consensus of opinion to be overwhelmingly in favor of the field location plan.

To collect the necessary data when running the preliminary line for making a complete topographical map upon which all possible locations could be projected, it is needless to assert, would cost many times what it would to run a preliminary line over these possible routes. Futhermore, to run a random preliminary line and accurately determine all topographical features within a lateral range wide enough to cover any probable divergence of the located line would cost more than to run a close preliminary, even if necessary to back up repeatedly and shift the course.

Railway location, that is field location, calls forth a particular faculty of mind that is not required in other lines of engineering work. The successful locator must have, to use a common expression, "An eye for the country." I have met many engineers in my experience who were successful and competent as designers, and in construction, but failures on location. They lacked the faculty of grouping together quickly and in their proper relations, the controlling features of the country--that comprehensive mental grasp extending over wide areas. Of distance, altitude and directions their conceptions were valueless until reduced to figures which they could manipulate. They might have been expert map locators if allowed the time and expense for collecting data, but as that system was not in vogue they were simply failures. I once traveled with a railway official, not an engineer, over a proposed loca: tion, who could only keep in mind his directions on section line roads by carrying a pocket compass in his hands.

The picture which Mr. Schenck draws of the locating engineer burning the midnight oil in working out his location on paper, is enough to paralyze that system of location. It is always conceded that the burdens of life in a locating party fall the most heavily on the shoulders of the back flagman. He is the pack horse of the party, bringing up the rear, loaded with all the surplus clothing cast off by those ahead, in addition to two or three bundles of stakes and a few extra axes, brush hooks, flag poles, etc. His woes are truly great, and there is little competition for his job. But if this system of map location supplants the older method and the locating engineer is driven by force of circumstances to perform his nocturnal labors by the lurid light of a smoking lamp between the hours of 9 p. m. and 2 a. m. while the night winds are howling around his camp, and his co-laborers, oblivious to their troubles, are playing trombone solos under their blankets, there will be no difficulty in filling the position of even back flagman with talent of a high order.

Willard Beahan, M. W. S. E.—You see before you to-night an instance of the superfluous man, for I was brought down here from Minnesota by President Finley, to insure this paper being discussed. I will speak of one or two things that have not been touched upon.

I assume that Mr. Schenck did not write all of the paper that he started out to write, as he distinctly says in the beginning that he will speak of concrete, bridging, etc. In closing he says that on account of the limit of the paper he has not been able to touch upon these topics, so that evidently the subject got too broad for Mr. Schenck, and we have not the full paper which he intended, in the first place, to write. In the first part of the paper in regard to railroad engineering, I cannot quite agree with Mr. Schenck in his criticisms of the Southern Pacific and of the work of my acquaintance and friend, Mr. Hood. He worked a locating party for that company and the Central Pacific R. R. continuously for 13 years. These methods of his were a growth from experience. Those of you who are considerably older than I am will remember that in the early days we were very careless in our methods. Mr. Hood is naturally a methodical man. He abhorred an error. Naturally, as he came to be chief of a party he became more and more accurate. He had charge of the location and was responsible for it. The result was, that he built up this system of extreme accuracy. In all probability he was a little more accurate than he needed to be. However, I have spent $100 per mile in increased average cost of construction, in the endeavor to correct instrumental errors made by the locating party. Mr. Hood was a needed reformer in the early '80s.

Another point you must remember. Mr. Hood's locating party was a machine. There never was but one engineer on it or anywhere near it. The reconnaissance party were ahead in an advanced camp and did all the office work. Then the line was located on the map and sent back to this field party and then the field party ran in this line, as a machine. Of course, working in that way, this office work and field work was very closely done. But there is much to be said in favor of Mr. Hood's method. The principle of double centers is excellent. The principle of having your back sight equal to your foresight in leveling is good. In some other respects I think he went too far.

Mr. Schenck's criticism of the loop I cannot let pass. There had been loops located before, but Mr. Hood did not know it. I am very much surprised to read Mr. Schenck's statement, as I cannot conceive that Mr. Hood would have used a loop when a short cut would have answered every purpose.

I was struck by one remark, where he mentions the characteristics of each road for which he has worked. His paper is the more valuable, because of his broad experience in the practice of different roads. He says that the quality he remembers of the Pennsylvania Road is that of "common sense." When you can say of any road which has employed you at any time that you remember them as using "common sense," that is high praise. I have been impressed with a peculiarity of the Pennsylvania Road—the care with which they consider the expenditure of a dollar. I do believe that road gets more out of a dollar expended than any other road in the country. The reason they get it is because it is the only road that is not under-manned, for they have plenty of good men. They can buy a railroad like the B. & O. and equip it with excellent men. They always have plenty of men. If you go into their offices you do not see papers stacked up high on office desks. They have plenty of men to take care of the work, but they are much more careful about their improvements; about laying out their money, and when they do lay out a dollar they take good care that that material is well taken care of. The west and northwest have much to learn in maintenance, and the Pennsylvania Road is the one that can teach them. I believe there are many roads that do not get as much out of a dollar, because of lack of experience.

You do not find the Pennsylvania Road putting in ties in September. When they lay a new rail they take care of it. We buy the rail and we cannot afford to take care of it. I know whereof I speak. At one time when I was taking care of a lot of steel rails a spasm of economy struck the road. The superintendent reduced the "force" and I complained. I was informed that the pay roll exceeded the appropriation and my complaint then did no good. It finally went to the president, a Pennsylvania R. R. man, who said we must keep the joints up until the ground froze. The Pennsylvania people are never too poor to take care of their new steel. A man there would be hung to a telegraph pole if he neglected to take care of steel the way some of the other roads do. I do not quite agree with Brother Schenck in regard to reconnaissance. I divide the reconnaissance into two parts—one for route and the other for line. When I am locating a railroad between two terminals, I always go over that line at least twice before starting the party. The first thing I do when I get a letter of instruction for a line of road between three or four points is to draw a line from one point to the other, then to the next controlling point, and so on to the last. Now, if I can run a line from A to B and C and D and get a desirable alignment and gradient, then that is the line for me to locate and build, and if that is true, there is no need of my considering another route. Therefore I ride over that entire line of 100 or 150 miles as marked on the map. Ordinarily I find I cannot use that line; there are difficulties in the way. As I come back, I plan how I can avoid them. I like to ride over the route a number of times and find the general route and then start the preliminary line. This reconnaissance for route I make with pocket instruments. On a large scale map, I put in all the notes I can get, and I take many notes.

For reconnaissance for line, on this same map I mark out my line as closely as I can, from recollection and from my notes. I go over it again and mark it still more closely and make notes so that the assistant engineer can follow my topographical sketches as he works the party. I keep ahead of the party all the time; away ahead—the farther the better. I never keep less than 20 miles of completed reconnaissance ahead of the party on preliminary location.

So much for the reconnaissance for the line and reconnaissance for route. Now for the location. I do not make a patch-work-quilt map, nor continuous-roll map because a patch-work-quilt is too bulky; and a continuous roll will not stay in the direction. I like to make a map in sheets. Having platted these two or more preliminary lines on these sheets I get as far ahead as I can from that camp with the line work in the field. While the party is still at work on preliminary I go back and take all the notes I need for location. I make a paper location—possibly the night before, or try to do so—but I really make it in the field the next day myself with pocket instruments. Then the man who works the party for me runs in the location the next day. You will see that method depends on reconnaissance and lots of it, and good reconnaissance, and paper location made by the chief of the party in the field just before you are going to do the work. I would not make it finally in the office at night, but of course Mr. Schenck is a very hard worker. It seems to me there is no need of overworking in this way.

I was brought up in Texas among the Indians and on the plains. Our chief engineer—an old army officer—said the chief of a party consisted of two things—a locating engineer and a quartermaster. This was true down there. The subsistence there was certainly important. While I was ambitious, I soon found out that if I fed the men well I could get more out of them. On just that principle and no other I cut the cost of location on Mr. Gould's southwest lines in two. For a term of years we found that the pay-roll was 60 per cent of the total cost, and the subsistence 17 per cent. Now you will see that if you put an extra dollar in the subsistence you would probably save money for the company since subsistence is a small item compared with the pay-roll. I believe thoroughly in taking care of a party, and there is no joke at all about it. It is a business proposition—an engineering proposition, and undoubtedly a wise thing to do. To take care of a party doesn't mean buying all you can think of. The subsistence lists given in Mr. Schenck's paper are very excellent and very specific, and are valuable in that respect.

H. J. Slifer, M. W. S. E.—I have sometimes wondered, particularly in the last few years, where I received my early training in burning the midnight oil; Mr. Schenck's article has proven to me that it must have been with my earlier experiences in the locating party.

In regard to the paper and the various comments given, I would like to ask, if the question could be answered, what effect would this evening's proceedings have on a young man just starting in the engineering profession. To my mind, he would admit that general engineering, judging from what has been read, is too abstract, too comprehensive, whereas, to the practical mind, it is one-fourth theory, and three-fourths hard common sense.

An amusing instance in connection with location comes to my recollection. It is along the line of long tangents, the one in question being a 16-mile tangent. An inspection party was on the cupola of a caboose car. A gentleman, who was a visitor, had his son, a boy about ten years old, with him. After hearing some talk of a long tangent, he said, "Papa, that is a good straight line that way (as a tangent) but no good this way" (for grades).

Referring to the Pennsylvania R. R., I did receive my earlier training with that road. Previous to that time, however, I served under Mr. Wellington, with the Mexican National Construction Company.

Some of the things mentioned to-night by Mr. Schenck and Mr. Beahan in connection with the Southern Pacific Company reminded me of certain things we were required to do by the Mexican National Construction Co. I think there is an expensive nicety in some of the exactness of technical engineers.

I know this was noticeable in staking out curves on a preliminary line in Mexico. I think, too, this applies to the Southern Pacific.

The Pennsylvania Railroad has been referred to as a railroad of common sense, and one that received full returns for the expenditure of every dollar. I am reminded of the experience of a young man who was "brought up" on the Pennsylvania Railroad, and who, possibly a dozen years ago, was applying for a position on one of the railroads in the great west. His recommendations of course were received. An officer of the road remarked, "Young man, your training has been good; there is no question about it, and no one can criticise the training of a man from the Pennsylvania Railroad; but there is one thing you have never learned there, and that is economy."

Having secured the position, and spending a few years in practicing economy with that road, he had occasion to interview the managing officers of another western road, in regard to a position. He gave his experience with both railroads, when he was greeted as follows: "Young man, your training has been very good, but there is one thing you have never learned with either of these roads—strict economy."

I think, however, the managers of the western railroads make a mistake when they say Pennsylvania Railroad men are not educated along the lines of economy, and I say this after an experience of 23 years. I have seen more wasteful proceedings in the west and northwest than I ever did on the Pennsylvania Railroad in 9 years, and I agree with Mr. Beahan when he said—"If a man neglected new steel rails the way he and I have had to do he would be hung on a telegraph pole."

I agree with Mr. Schenck in regard to a good subsistence list. In regard to a horse eating his "pack off his back," I have been compelled, on the North-Western Railroad, to haul at least 10 per cent more feed for the horses in the winter time than I did for the men, simply to keep them alive.

I have also been compelled, when the roads were heavy, when we could not use the sleds, to start a pair of horses up the line, and divide a barrel of sugar and a barrel of flour between the camps.

You cannot feed men in camp too well, neither can you provide them with beds too good.

The subject of field location, proper location, etc., I think is simply the method to which a man has become accustomed.

The question of general engineering, earlier in the evening, recalled a little incident which may bear on the subject. It was in Appleton, Wis., and an engineer was called upon to do some work for the city; after the work was half finished, he changed his plans. I happened to know the engineer and was commenting one day upon the change and the error that had caused it. A prominent physician, also a wit of the town, was standing by, when the conference came to a sudden end, by the following remark from the wit: "Engineers and doctors always have the opportunity of burying their mistakes."

E. E. R. Tratman, M. W. S. E., Chicago.—In regard to the faulty location which has been spoken of in the paper and in the discussion, I think it should be pointed out that in many cases the responsibility lies with the company rather than with the engineer. It is a very common thing for the company to require the location to be rushed, or to impose arbitrary limitations as to grades, curvature, route or other matters. The only thing then for the engineer is to do the best work he can within the prescribed limits, or with the best possible combination of rapidity and efficiency. As an example, take the third plan shown by Mr. Taylor, although I have no idea as to what plan it represents or under what conditions the survey was made. If the engineer worked his location from the left, he would find one valley opening out in the general direction of the desired route, while the other appeared to diverge from it. As he approached the summit and got into heavy work, we can imagine his heart sinking at the possibilities before him. With plenty of time available he might have gone back and tried the other route, but if he was being continually urged by headquarters to hurry up, he may have plugged along in desperation until he found a way opening before him again. Anyone going over the ground after construction might easily see where a better line could have been placed, and might not unnaturally blame the locating engineer. It is also not improbable that the location may have been done by a man with insufficient experience to be entrusted with such work, but who was willing to accept the pay the company offered.

Another thing to be remembered is that the numerous improvements in line and profile now being made on nearly all important railways do not necessarily result from bad original location. Traffic conditions, and especially the enormous increase in train loads within recent years, have been the principal reason for many of these changes.

The improvement of the Chicago & North-Western Railway at the crossing of the Des Moines River valley, near Boone, Iowa, is a case in point. The original line was developed down both sides of the valley to a low-level bridge over the river. The new line runs directly across the valley, crossing the river by a high-level bridge. At the time the line was originally built, however, the construction of the high embankments and the long and high bridge was probably out of the question, for financial and other reasons. It was real economy to avoid such difficult and expensive work by a larger location with light work and a comparatively small bridge. The growth of traffic and the increase in train loads, however, made it eventually wise economy to build the new line, even at great expense, thus facilitating the operation of heavy trains.

There is one point in location, however, in which many engineers have apparently been weak, and that is in failing to give proper consideration to the transportation side of the question. A comparatively slight change in location may have a large influence upon the future problems of train loads and general operation. The criticism of the Pennsylvania Railroad on the ground that men do not learn economy in its service, is undoubtedly made as a rule by men who consider economy as synonymous with cheapness, and it is singular how very generally this mistake is made.

Samuel M. Rowe, M. W. S. E.—To the railroad is largely due the unparalleled development of our country and our nation as well as the world at large. It is undoubtedly the highway of the world, and in importance is second to no other, and has required the thought and study of the best minds both in engineering sense and in a commercial line of ability. Since early in the nineteenth century when the use of steam became well fixed as a power it has been a matter of growth and development, first falling within the scope of one mind, but gradually enlarging in scope until it now calls for the work of many minds, each of its various phases requiring and justifying in dividing it into many specialties, covering almost the entire field of mathematics, physics, mechanics, general engineering and commercial business. In the education of the student of today the elementary parts of each of these are acquired so that the student may follow his bent of desire, but is oftener governed by the opportunity first offering. His preparation being to him what the carpenter's tool chest is to him, his success depends on the skill and judgment with which they are used.

In railroading now if success is achieved in any one of the various special divisions, the achievement is such that any one may be proud or at least well satisfied.

Mr. Schenck's paper on the "Diversity of Practice in General Engineering on American Railroads," is valuable in that it treats of certain salient matters belonging to practice at the present age. I do not understand that it was intended to be exhaustive, as this would be impossible in any paper that could be presented to this society of engineers for one evening's reading. To do so would require a good-sized volume or more. The treatment of the points covered is all the more valuable, however. In treating these matters it must be remembered that railroads are of comparative recent origin and that the art of railroad building is scarcely yet out of its infancy.

Some of you may remember a little locomotive that was exhibited at the Columbian Exposition a few years since, one that ran on the first railroad in the state of New York. The name I have forgotten but I know that it was six months younger than myself. It was my good fortune to be quite intimately acquainted with the superintendent of that road at that date, August, 1831, the Hon. Geo. L. Schuyler, formerly a competitor to Commodore Vanderbilt and later a partner in the steamboat lines on the Hudson River. His description of the methods and appliances used in those days was very interesting and at this date might excite amusement. Thus, early attention was called to the danger to the brakeman in coupling cars, and to obviate this chains and hooks were attached to each corner of the cars so as to couple them without going between them.

The railroad of to-day is the result of a gradual development and growth, both in methods of building and character of appliances, hence in discussing the work of engineers of earlier date we should criticise with great caution.

In the earlier periods of railroad history a technical training, such as is now no doubt possessed by any of the younger members of this Society, was largely wanting among the men on whom the burden fell; hence they had to make the deficiency up largely in resourcefulness, energy and the exercise of common sense. At later periods the experience began to be available, and as railroads grew and multiplied, more advanced and perfect methods were formulated and applied.

The reconnoissance is the first necessary step in the practical construction of a railroad often preceding the actual money in bank. It is sometimes said that "poets are born, not made," and it is probable that it is somewhat so with a good locator. However this may be, there must be a certain amount of instinct brought into play. In the roving bands of the buffalo of the western plain who marked out the paths that guided the first reconnoiterer, John C. Fremont, the "pathfinder," had this instinct. It may be instinct or it may be that well known law of nature by which a body will move in the line or direction of least resistance.

In any case the locator must have a keen sense of elevation and distance so as to quickly determine where he can go easiest between points. Mr. Behan's remark in regard to the necessity of a good horse is well to the point; I found three good horses none too much in a mountainous country.

As to the best method of running a preliminary after the country had been well studied would seem to be to run a transit line under careful supervision, taking notes as to points to be bettered with topography covering such notes, then calculating alignment based upon this preliminary. In a country not very rough this will often give a good located line.

This matter has, however, been gone over so well in this discussion that it would seem better to go somewhat into generalities.

As I have already called attention to the fact that railroads have grown from infancy during the short period of one human life, I will try to review the history of this development.

Of course the tramway and its uses cannot be said to be new in the same sense, neither the sciences of mathematics and physics can be said to have advanced materially since the birth of the steam railroad, so that their application in the higher sense has but little to do with the practical part of railroad building. In fact, the student fresh from the college, no matter how thorough may have been his course of study, is really only at the threshold of railroad engineering. He is, however, thoroughly equipped to enter upon the business, although it is still practically an unexplored province. But without energy, resourcefulness and good practical sense and judgment, his high attainments will prove of but little service. Many known railroad builders thrown into responsible positions, although living at a period too early, when it was almost impossible to secure this higher early training, have proved able and efficient railroad builders.

That railroads built fifty years ago are now far behind the time and needs of the present is no proper grounds for criticism. The conditions at that time called for just what was built. Then it would seem to be true that in this country each step in development of needs has always found the men to meet these needs and will continue to do so. From past observation I think it can be safely said, irrespective of educational opportunity or preparations, that the real railroad engineer is made after he enters the field of practical experience.

The refinements of instrumental work mentioned, necessary in canal work, are scarcely practicable and are unnecessary in railroad track work except it may be in placing important superstructural work. Indeed, an engineer with orders to construct a line by a certain fixed date must not stop to apply these refinements, but must do each part of the work so as to get it all done in the time specified. It really makes little difference if levels are one-tenth foot out in each mile. In one case a seventeen-year-old boy cross-sectioned fourteen miles, using a profile made in the field, and was six-tenths out at the close, as determined by a careful check afterward.

If the instrument is understandingly handled it can be depended upon to do the work with sufficient accuracy.

As to reconnoissance, the extent and conditions will largely affect methods.

The termini govern points of starting and ending; mountain ranges, streams, valleys and divides to be crossed, the nature of the stream and its watershed, and flood levels and many other matters, affect this part of the work. The choice of route in some portions will be between the cost of a valley route or following a divide. If the valley is that of a troublesome stream, a high line on the divide is often the safer and the cheaper. Of course the crossing of mountain range is governed by the lowest pass, the crossing of valley and stream by the best practical point, and consequently the intervening portion of the route should hold as nearly as possible to the "grass roots," and when cheapness is paramount, as it usually is with pioneer lines, the curvature will be largely determined by this.

The "grass roots" method is the practical one, as there must be solid ground to support the track all the way and curvature will fit the mountain side to the easement of the amount of grade. A thorough reconnoissance is just as essential as thoroughness in the other parts of the work.

H. H. Jackman, M. W. S. E. (by letter)—I would accentuate the statement of the author regarding the neglect in discussion of matters pertaining to railway location and construction, aside from their larger structural works. This neglect is not only true of our engineering societies but of the engineering journals as well. When the magnitude of these interests involved is considered in connection with the comparatively meager attention they have received from these sources, the necessity is realized of a larger dissemination of literature on these topics, and the belief is formulated that the author's paper will, in a large measure, be the means of bringing this about. When this reaches fruition the experience of one engineer will have become beneficial to that of another; and such methods will only be practiced as are demanded by the difference in local conditions. In this manner recognized standards of procedure can become established, and the now prominent features of local treatment, so noticeable in the practice of different roads, will disappear in the "balancing of the forces" as a "resultant."

Much has been said in these discussions regarding the different methods to be followed in planning and executing a reconnaissance. The writer's experience, covering both prairie and rugged mountain work, is that radically different methods must be adopted and carried out in dealing with these different physical conditions. One engineer may insist on a so-called "paper location," while another will as strenuously advocate the superiority of a field location. The probability is, that each, advocating from the standpoint of his individual experience, was correct in the particular instance he had under consideration—neither system being best applied to all situations. A field location may the more safely be relied upon in a prairie country; while in a mountainous one, whether wooded or not, it would be wholly inadequate to the requirements.

The point has been raised in the discussion as to the advisability of the chief engineer attending personally to the preliminary reconnaissance, or the leaving of this to his assistant. Into the proper determination of this point the personal equation largely enters. In addition to this, however, attention should be directed to the great assistance afforded the locating engineer by the use of the topographic sheet and geologic folios of the U. S. Geological Survey, so far as they are completed for the sections of the country which they cover. With these in hand the chief engineer is enabled to indicate to the locating engineer the controlling points which he desires observed. By following the contour lines he can closely approximate the length and general course of a preliminary line on any assumed rate of grade. With the limiting grade in mind he is enabled in this manner to determine approximately the possibilities of a line between any two given or assumed points. A close study of these sheets in this manner will afford an intelligent comprehension of the scope of the problems to be encountered, and as well, the best methods of attaining their solution.

As a means of indicating to the chief engineer at his headquarters what is being accomplished by his parties day by day in the field, a system of daily reports should be established whereby the field-notes, both transit and level, are to be copied each evening onto specially printed blanks, and transmitted by the next mail. A member of the chief's office force then at once plats upon a continuous map from the transit notes; and with the level notes a continuous profile is kept up. For the map a scale of 200 feet to the inch will be found to be convenient. In this manner the headquarters office is acquainted at all times with what is being accomplished at the front. This system is being successfully used by the writer, whose present work involves the location of a line across the Shenandoah, Allegheny and numerous other mountain ranges of the two Virginias.

One other point is suggested by reference in the discussion to the so-called "butting process." It is, that instead of endeavoring to carry a first preliminary line up a hill or mountain in a range, the engineer first, by reconnaissance, should determine the lowest and narrowest point in the crest of the range, and consider that as a fixed point. He should then from this back a line down on his maximum grade. From this running can then be determined the lightest grade possible to make the total rise. The advisability of this method is apparent from the latitude to be found in the location of the point from which to commence the ascent as compared with the objective fixed in the summit.

Regarding the method of taking and the use made of topography, there seems to be much difference of opinion. The writer's judgment in regard to the use of contour lines versus figures indicating the topography, is unhesitatingly in favor of the former, on account of its great perspicuity. In the use of a plus or minus gradient the eye follows from one contour to the other without confusion or conscious effort. In the construction of topographic sheets much aid to the convenience of their use will be afforded by drawing contours of different colors. In representing a hilly or mountainous country the drawing of the lines which represent each 25, 50, 75 and 100 feet with a different colored ink adds to their convenience of use. These should also be heavier than the intermediate lines, which are better to be light in weight, but clear and distinct. Each 100-foot line is the more easily picked up if it should be a dotted one, or in some other manner drawn differently from the others. At a convenient number of places the small figures indicating their elevations are placed upon each fifth or tenth line, depending upon the degree of slope being encountered. The lines should be broken to receive the indicating elevations. These contour sheets when completed bear a resemblance to the maps of the U. S. Geological Survey. In their construction the topographer draws the contours in the field as the work of taking the notes of same is in progress. In the evening the lines penciled during the day are inked in. They are now ready for the locating engineer. The first work of projecting the location on the topography sheets is accomplished in pencil, and as the topography is in indelible ink, erasures can be made with impunity. The sheets should be composed of a good quality of bond paper about 14 by 20 inches in size. After the alignment made from this projection is staked out on the ground, a new platting is made in red ink on fresh sheets. The topography is now taken over this newly located line and platted as before. These sheets are turned into the office of the Chief Engineer from time to time, and become a part of the permanent records of the office.

Two years in determining where to build, and two or three weeks in deciding whether to build, has been the policy pursued in the instance referred to, as against the usual policy of railway company directors in taking "two or three years in deciding whether to build, and two or three weeks to decide where to build."

CLOSURE.

Archibald A. Schenck—The writer so fully, in his opening of the topic, stated his intention of merely noting some things concerning the topic, that the suggestions about the paper not covering the whole field of general railway engineering, do not appear to be well taken. The first requirement of a society paper is not that it shall be complete and full, but that it should present topics for discussion and evoke discussion. The object of a society is to bring mind into contact with mind, and evolve the best result and practice from the judgment and experience of many.

Professor Taylor, in his criticism of the name “General Engineering” in railway construction, appears ignorant of the fact that the name has been very widely adopted in railway work, and is used to exclude, not include, the topics he names. It covers generally railway engineering, except bridge engineering, signal engineering architecture, mechanical engineering and rolling stock. It is a convenient term and railway civil engineers will doubtless continue to use it, Professor Taylor and his calomel to the contrary, notwithstanding. Life is too short for us to use the term “locating-grading[*]-masonry-trackwork engineer,” even to accommodate Professor Taylor. I have had, in the last 25 years, many efficient young assistants, most of them technical graduates, who were practicing and intended apparently for life to continue practicing this general engineering only. If they were quacks, it escaped my notice.

We take advantage of Professor Taylor's remarks, however, to call attention to the unreasonable demand that is made upon the civil engineer by most capitalists, some railway managers, many of the public, and a few young engineer graduates, that the civil engineer shall know pretty nearly everything. He is not permitted freely to specialize, as is the lawyer or physician, without having a slur thrown upon him; in fact, being called a quack because he does specialize. He is expected by those named to be an expert in location, grading, masonry, trackwork, minor railway structures, architecture, bridge engineering, electrical engineering, mechanical engineering, rolling stock, signal engineering, water supply, drainage, city engineering, common roads, land surveying, geodetic surveying, river and harbor improvement, terminal facilities, gas works, mathematics, high and low, geology, chemistry, physics, engines, pumps, paints and plaster. The technical graduate comes to us from college faintly tinctured with most of these, but most graduates have the good sense in a few weeks to realize the fractional nature of their training, and that their real study and training begin after entering upon the practice of their profession. Moreover, what the learned professors are instilling or endeavoring to instill into their pupils is largely based upon what the general engineer in actual practice finds best, and which is the information the professor borrows and administers, in homeopathic doses well diluted, to his students under the title of scientific training, instead of calomel.

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[*] The words “grading” and “graduation” are variously used for excavation and embankment of railways. The word “graduation” was formerly much used in printed specifications of railway work, to indicate the species or class of work, “grading” the graded roadbed. Both have been coined by engineers for useful purposes, but the word “grading” appears now to be more generally used for both the class of work and the graded roadbed.

Some misunderstanding seems to exist that the man who makes and studies a paper location is not as fully a field locator as the man who works only in the field. The contrary is true. The paper locator goes out each morning much better equipped by his evening study to do genuine and good outside work than the locator who has joined Mr. Armstrong's "trombone chorus" at 9 p. m. The evening student has carefully run several possible lines, studied them closely in profile and estimate, made the ground familiar to his mind in advance of locating, noted in advance every point requiring special examination or possible revision the next day, and generally keyed up his mind to rapid and effective work in the field the next day. He is more truly an outside worker than the man who has thrown off his important work at supper time and taken it up mechanically at the same stage of knowledge after the breakfast hour. There is no such thing as "work" about this evening study. To a man fond of locating, few things are more deeply interesting than the studying out of one possibility after another, and hunting for the best. There is no hunter devoted to the chase who finds greater enjoyment and greater stimulus to endure hardship than does the hunter for the location in a difficult country. He drops his pencil reluctantly at night, and is eager to get the party moving the next morning. To the subordinates there may be drudgery in location. To the locator it is not cash-per-hour work, but enjoyment from start to finish, minus, of course, the physical trials and discomforts.

On the other hand, the field locator claims to be able at first, or at most at the second attempt, to run off the only and best line along each part of the location without repeated tentative locations. He poses as the infallible man, a machine before, a machine behind; the connection between the two about as rigid as a piece of a machine. Instead of having tested many lines and approached the result with caution and some little humility, he has ordered off in cock-sure fashion under the inspiration of native genius, the one infallible line. Then he goes off, perhaps many hundred miles, to furnish another connecting strip of infallibility to another pair of machines. Many have wondered why the public have dubbed the Snuset Route the Seasick Route. It is from lack of plentiful supplies of midnight oil in study of topography and of broader and better possibilities than can be obtained by peering around a hummock or marking crow's feet opposite the bare preliminary as the infallible spots for location; the reason for them forgotten a few hours after being noted. Yet, if the locator can bisect the crow's foot by the predestinated fraction of a hair, the highest object has apparently been attained. Or a number of bull's eye grade points have been entered on the otherwise blank paper, and careful calculations made for hitting each and every one. Modern curvature and gradients, really productive of ultimate saving, are as fully understood and valued by the paper locator as by the random field locator. The effort of the office study is to avoid needless and uneconomical curvature and gradient, by greater breadth of examination and more close and repeated analysis of supposed obstacles.

The writer called for grasping fully the topography of the proposed or possible routes. By possible is not meant "possible of operating," but "possible of selection" because of merit. The object of the careful reconnaissance referred to, was to eliminate the manifestly undesirable preliminaries and limit the running to such as might possibly be finally selected for location. On these the topography should be sufficient to permit a proper selection of the best. The close work of topography will of course be along the preliminary selected for the actual location. Mr. Armstrong states that "all possible alternatives not eliminated by the reconnaissance should be run and carefully platted;" also that "topography enough should be shown to show the salient features of the country a few hundred feet either side of the preliminary line." If such plat and topography are used to determine the location, this constitutes paper locating. If not so used, why make or take them? Why throw the information aside and attempt to see the location through to a finish, by trying to see it all horizontally on the ground, much as one would try to read the contents of a sheet of paper by looking at its edge instead of from above, as with a map? If anyone will for a moment get into mind how horizontal distance must vanish into insignificance viewed nearly horizontally, this must be apparent. When viewed in spots in succession, the mind fails to remember the features of each, and the true relation of one spot to another. The field locator is hemmed in by hill and hummock, his sight interrupted by trees, timber and other obstructions, his judgment diverted by false summits and overlaps, and not clearly realizing (no man can by eyesight alone) the rates of long light slopes. He may profess to see the proper line through long stretches of hundreds or thousands of feet of this obscurity, into which he cannot actually see sometimes a hundred feet. The paper locator has two or three miles of ground, and has it correctly, before his eye at a glance. To equal his advantages and see as much, as quickly and as correctly, the field locator must needs have seven league boots and a seven league neck. We can to advantage quote a sentence from Wellington: "No engineer of any standing or experience believes that location offering any difficulties can be made to advantage in any other way than from topographical notes embodied in a more or less elaborate topographical map."

What many engineers, as quoted by Mr. Armstrong, really oppose, is locating exclusively from a map in an office. We can hardly understand their objection to be against gathering information from every source (which map locating means) before beginning operations on the field location.

It is noted that Mr. Beahan also advocates paper location, made "possibly the night before," and also a "paper location made possibly by the chief of party in the field just before the location is started." This is in effect paper locating, with the drawbacks noted, that numerous paper locations cannot be made and compared unless by expensive detentions to the party. In such case the engineer is doing in the field, holding the party, what he should have done the night before, and could have done better because under better office conditions, than sitting upon a snowbank with the winds howling around the locator. If office conditions are poor and the lamp smoky, this implies poor commissary and organization. It is pleading one defect to excuse another.

There are doubtless some types of country where paper locating may be abandoned for field locating only. They are very open, simple, and nearly treeless, yet caution has to be used lest very extended but almost imperceptible swells, pitches, depressions and bowls may be overlooked, and a line secured which, though usable, does not represent the best. Even in one of the simplest and most defined cases, what might be termed the "baby work" of locating, some defects might be avoided by occasional paper study. This case is a location in the flat bottom of a narrow, treeless valley. The line passes from convex hill point to convex hill point. The engineer cannot get away, or go far wrong in general route. Any line that anyone, even a person not an engineer, might locate, would be usable, and fairly good. Yet even here needless swings may be noted, tangents needlessly broken into two or three, curves employed in mid-valley, curves placed on the concave side of the valley or hillside; hill points rounded in fill with side borrow pits; basket handle curves, needlessly used. Along bluffs, where close special platting and fitting are required, the line may be forced into excavation, with huge waste banks paralleling the side cut, and needlessly high and shattered slopes calling for still more excavation.

The reference to the use of horses in reconnaissance explains some of the indifference to map location, by indicating the character of country that is in mind. A treeless and prairie country where the horse can go freely either along section line road or "across lots," is generally not the sort of country calling most urgently for paper location study, nor is it the sort of country in which are required what may be termed the "major operations" in location. The author indulging in reminiscences of the localities where he has located, and attempting in imagination to place or utilize a horse, feels somewhat compelled to asked for the winged horse Pegasus.

The rugged and densely timbered slopes of the Alleghenies, with the laurel thickets where even a man on foot can hardly penetrate. The rocky cliffs and shores of the Hudson from Haverstraw to Newburgh, where the horse would have to be taken into the rowboat with each engineer party used. The deep canyons of the Lower Kicking Horse in the Rockies, where even the narrow foot trail afterwards made, was 900 feet above the river. The rough and timbered slopes of the Beaverfoot on the east slope of the Selkirk Range, with the location several hundred feet above the valley bottoms, cut by canyons 150 to 335 feet deep, which Pegasus could travel better than the engineer. The tangled mass of canyons and timber, ten foot logs three deep, of the Ille-Cille-Waet Valley on the west slope of Selkirks. The rocky shores of the Columbia, penned up between the river, and cliffs 1,500 feet high, where much of an attemped road tobogganed into the river. The rough and narrow North Santiam Valley, on the western slope of the Cascade Range, where the writer himself, fairly agile and squirrel-like, worked hard some days in getting seven miles advance in reconnaissance. It is difficult to see where in such locations a horse could come into action. There is no engineer who could accomplish much by purely field locating, with not even a half acre "field" within several hundred miles in some cases, the vision limited, by hills, cliffs and turns of cliffs, or a jungle of fallen and growing timber, large and small. By the time one of our human compasses had forced his way through the thickets, and crawled along, over or under several layers of logs eight or ten feet in diameter, his internal north point much of the time would be pointing down into the bowels of the earth, or up to the logs overhead, or anywhere except northward.

Mr. Armstrong's suggestion that the methods of work and form of returns should be left to individual choice and caprice is contrary to all development and advance in railway or other spheres of work. In bridging it is not sufficient that an engineer secure results in his own fashion by getting a train across a hole somehow, with nothing turned in to the company except a thread of line on otherwise blank paper, or that he calculate the stresses in his head and throw away his paper work, assuming he will lower his individuality by using paper. The general type of structure suited to each type of locality and service has been a matter of development by many minds through many years, until the present better types have been evolved. Then, when throwing aside individuality, these types are used, both stress sheets and plans are turned in to the company for examination, for record, and for use in repairs and maintenance. The field engineer in location, having constituted himself the final arbiter, sends in only a picture of a thread, plus sometimes a little hen-track topography worthless in horizontal dimensions or elevation, hardly better than the accidental thumb marks on the sheet.

A word about Mr. Morgan's "grizzly," namely capital. The writer has been close to the beast for thirty years. In general he has found the grizzly a fairly sensible, and sometimes an exceedingly kindly brute. In fact, the grizzly has for many decades been patiently acting for some engineers as a scape-goat, carrying numberless mortal coils of needless curvature that inefficient engineers have shuffled off upon him. Personally, I have never known of a request by capital upon the engineer to put more curvature into a line in order to save money. The capitalist has taken what the engineer has presented as the reasonable location, and decided to build or otherwise upon the basis of the line and estimate as presented. Doubtless there have been cases of colossal fraud by construction or improvement companies upon minority stockholders of the railway company proper, where an understanding has been had with the engineer to get any cheap and crooked line that would line the pockets of the construction company's manipulators. That sort of grizzly the writer has not met. The principal vice of the grizzly is chasing the engineer over his route under time conditions not the best suited to good results. But economy is generally a false excuse for curvature. Grading constitutes generally only a moderate percentage of total cost. On that percentage, the saving by needless curvature constitutes only a small percentage. The actual saving by most needless excesses of curvature is comparatively small, and generally much less than the increased cost of operation, capitalized.

The human compasses referred to in the discussion are rare creatures, so far as the writer's observation go. In earlier years I made a practice on cloudy days of testing as many of these as possible, including the old woodsmen. · It was remarkable how few men were found who could carry a correct compass course in mind, and how seldom the best men did so. In fact, I know of engineers who have become hopelessly lost, team and all, immediately upon leaving the friendly guidance of a valley and breaking loose upon the summit plateau. But even this compass faculty is a lower and mechanical trait of mind, readily remedied by the pocket compass, and not at all indicative of a higher topographical grasp of a country by the mind. This grasp does not result from any mental azimuth exclusively, or from any innate genius in most cases, but from genuine hard work in continuous study of an area of country. The mind gradually modifies its previous views until a fairly correct conception is reached. But a little simple data of low grade, secured in advance by a low grade assistant, will greatly facilitate this conception.

The instances of poor location mentioned in the discussion are interesting chiefly from showing how an evening or two of study on a map of the area in question would have prevented the mistakes indicated.

The writer describes the "crazy quilt" map. This is in reality practically what Prof. Taylor and others have recommended and Mr. Wellington illustrates. Instead, however, of fastening the sheets together temporarily with thumb tacks, they were fastened together securely with glue, after having been examined in the field. Then the vacancies were filled with blank portions of sheets, glued into one rectangular map. This retained the whole in more orderly and systematic shape than if in a bundle, with edges frayed from handling, bored through with frequent thumb tacking, margins interfering, the necessity of a table for each examination, and the slow process of thumb tacking each in position for even a few moments' examination.

In response to an inquiry we would state that our experience does not show any one scale or contour interval suited to any one area in most cases. As the ground varies, these features theoretically would vary, and for the study of specially important points, should vary in practice. For a light country, 400 feet per inch with five foot intervals of contours can be used to advantage. In ordinarily rough country, 200 feet per inch with ten foot intervals can be used. In very steep, rugged hillsides and cliff work, 100 feet to 50 feet per inch, should be used. Contour intervals have to be decided specially for each case, and at cliffs of course may disappear occasionally from the map. In the large scales, points on proposed curves of large radius have to be calculated, and filled in with rubber or similar curve forms. To attempt to put numbers on scales of from 600 to 2,000 feet per inch would result in obscuring the country by the numerals, with few numerals, not sufficient in number to grasp the ground changes. Very fine, small figures are required, even with 200 feet per inch, but the making of such legibly is quickly learned, with a fine and hard pencil. The writer has used the 6 H Faber, painted red, such as are sometimes used by the U. S. Coast Survey in taking topography on rough paper. They are harder than the buff 6 H, though not of as good quality. Most dealers will insist that there is no such pencil.

In taking topography too much care cannot be taken to impress upon the topographer that taking anything not affecting the position of the location line, means wasting money.

The failure by most engineers to use stadia work more largely, as suggested by Mr. Boardman, has been a mystery to the writer. I have frequently at my own expense had stadia hairs placed in the instruments of others to secure their use, in some cases with double hairs top and bottom to meet the excuse of danger of error in leveling. I confess I do not know a half dozen railway engineers who use them largely. In rugged country the stadia method is not as rapid as some other methods; but in fairly level and treeless country it is by far the most effective. For rapid work in situation plans for structures it is particularly useful. The line of railway I mentioned, with 600 preliminary lines, was located before stadia hairs were known, or at least generally known.

Mr. Jackman calls attention to one important matter in locating; namely, that a grade line should be run downwards from a summit instead of upwards towards a summit. This was an axiom with the locators of the Pennsylvania school. The failure to obey it is apt to leave the engineer near his summit, squirming as badly for more distance as if he were planning a loop, and with no width of valley even for that desperate last resort.

CLXV.

ADMINISTRATION OF STREAMS IN IRRIGATION.

By Elwood Mead, Washington, D. C.

Read Nov. 5, 1902.

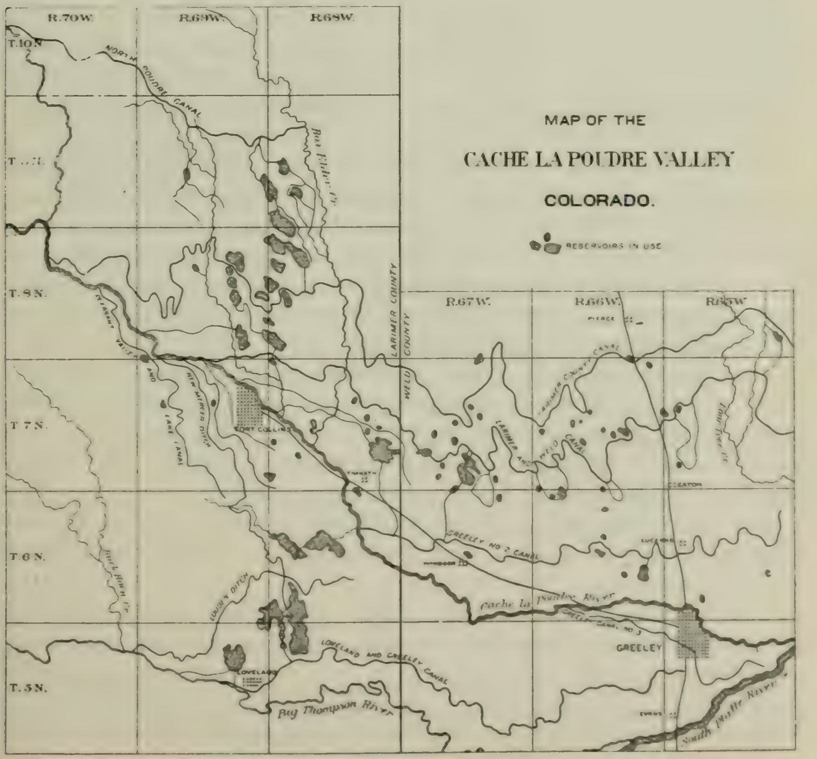
In the arid west there is no escape from the overshadowing importance of streams. Not only the prosperity but the very existence of civilized life depends in large measure on ability to use rivers in irrigation. Whoever controls the water supply practically owns the land it makes productive, and just and stable titles to water are of far more importance than deeds to the land on which it is used.

We have reached a period when the significance of these facts cannot longer be ignored. The water problems of the west are assuming national importance. In the suit of Kansas against Colorado in the U. S. Supreme Court, and the international questions created by the use of the Rio Grande, are examples of present conflicts created by turning streams from their courses. In its larger aspects the use of the rains and snows of the Rocky Mountains and Sierras to water the arid plains, affects the flow of the Mississippi, the Columbia, and the Sacramento, and will in time raise the question as to whether the farm at the headwaters or the steamboat below is to have the use of the water supply. Meanwhile, with an optimism characteristic of the west, development goes bravely on.

The use of western streams in irrigation has created a commerce in water of great and constantly-growing importance. More than $100,000,000—and some estimates make it twice this sum—has been expended in the construction of irrigation works. They begin with the rivulets far up on the mountain slopes and extend to the great rivers which wind their lonesome courses across the dusty plains. The area which these ditches and canals can be made to water is as large as the state of Indiana, and an area half the size of that state is now being irrigated. The main canals and laterals are so arranged that every square foot of this area is watered from one to five times a year.

These cultivated lands are not continuous, but are cases scattered over a region larger than any European country save Russia and which embraces about one-third of the United States. The water supply is taken from thousands of rivers, creeks and rivulets, is drawn from reservoirs, and pumped from wells. Its management and distribution require an army of men to patrol the canals, to regulate the gates by which the water is taken in and adjust those by which it is measured out to users. Claims to water are filed and recorded like claims to coal, oil, or placer mines, and a settlement of the water titles involves a determination of the rights which shall be recognized in the rains and snows which fall on mountain summits, and the harmonizing of conflicting interests of individual irrigators, of communities, and even different states.

In considering the administration of creeks and rivers we shall not be able to deal with the manner in which canals are operated, the contracts under which water is sold to farmers, nor the methods employed in its measurement and delivery. Either would be a large topic alone. I shall not attempt to define all the legal issues growing out of water ownership, because that would be impossible, nor to say much about engineering methods, because, in so brief a discussion, this would not be interesting. I hope, however, to make clear that the farmer under irrigation has to deal with knotty problems, of which the farmer who depends on the clouds knows nothing, and to place before you the relation of streams to the agricultural development of the west, to give you some insight into the meaning of a water right, the most vital and perplexing question which now confronts the farmer, the lawmaker, and the jurist of the western half of this country.


MAP OF THE

CACHE LA POUDRE VALLEY

COLORADO.

The most effective way of doing this seems to be to trace the growth of administrative methods on a single stream, to show how its waters have passed from public to private ownership, and how they are being leased, sold, divided and used, letting this serve as an example of what is taking place in thousands of other valleys between the Missouri River and the Pacific Ocean. To attempt to deal generally with this subject would only result in dazing you with the conflicting laws and diverse conditions of the 17 arid states and territories. There are complications enough in one valley to occupy one evening.

I first saw the stream we are to use as an illustration 20 years ago. I had traveled for 300 miles up the incline of the plains which lie against the eastern base of the Rocky Mountains. It was a country almost without inhabitants, and where it seemed that a light-footed and laborious grasshopper would have hard work to live. The last part of my journey was up the valley of the Poudre River near the mouth of which is the town of Greeley* and the site of the historic Greeley colony*, and at the upper end the town of Fort Collins and the State Agricultural College. This stream, which is too large to be called a creek and too small to be properly dignified as a river, has its source in the perpetual snows of the mountains. It tumbles down through rocky gorges for a hundred miles and then flows for 50 miles across the plain which falls away from the mountains to the east about 20 feet to the mile. Where the river leaves the mountains it is nearly 6,000 feet above the sea; where it joins the South Platte, it is 4,800 feet above the sea. Bordering the stream is a strip of irrigated land varying in width from ½ mile to 15 miles. Fifty ditches and canals divert its water. The one farthest upstream starts in the cañon, the one farthest down, 45 miles below. The largest canal is 60 feet wide, 5 feet deep, 75 miles long, and supplies water to 400 farms. The smallest ditch can be stepped across and waters less than 100 acres.

The first ditches were built more than 40 years ago in the vicinity of the stage stations along the line of the Overland Trail, one branch of which ran up this valley. At that time, everything consumed had to be hauled in wagons over 700 miles. The freight rate was 25 cents per pound, with no insurance from loss from floods or Indian raids. Even unskillful irrigation was a success. Hay sold for $100 a ton; cabbages brought $1 a head, and potatoes 50 cents a pound.

The founding of the Greeley colony in 1870 was the beginning of a new order of things in Colorado. Before that irrigated farms

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*Greeley, Colorado. The reader is referred to an iteresting and valuable account of the origin, settlement and evolution of Greeley, in *Harper's Monthly Magazine*, February, 1903, under the title of "A Decreed Town."—Ed.

had been too small and too widely separated for their owners or their owners' families to enjoy either churches, schools, or the advantages of social life. But the colony canal was large enough to create a community which could give its members all the comforts and institutions of civilization. Its success was quickly followed by other large projects which had their headgates farther upstream. Capitalists saw a new source of wealth in the melting snows. Irrigation development became corporate and, in a sense, speculative. In less than nine years over $1,000,000 was invested in canals and ditches which reached from the river for scores of miles out on the unsettled barren plains, and covered many sections which were not watered nor farmed for 20 years.

The promoters of these enterprises came from all parts of the country and the money which built them from more remote sections. The largest one was built by a Scotch company with money brought from Edinburgh. Colonists from New York enlisted their friends in two or three others. The promoters of these enterprises were spurred by rivalry to secure these hitherto unused resources of nature, and in the race for acquirement gave little heed to future consequences. No one knew how much water would be needed to irrigate an acre of ground, nor whether the river would fill all the canals after they were completed. The result was that ditch building far exceeded the capacity of the stream to supply water. The largest of these canals carries more water than the average flow of the river during the irrigation season, and all the water it carries can be turned into any one of a half dozen in August and September. When the snows are melting, or following cloudbursts, there are brief periods when the river will more than fill all these works, but it requires a continuous supply to serve farmers, and the chronic condition of the river is a need of more water than it will furnish.

Without some outside control, the position of headgates would count for everything. The canals farthest upstream would take what they pleased, those below would take what was left, and those farthest down would most of the time go without.

The lack of such division brought a crisis in 1878. The upper canals took all the water, leaving nothing for the Greeley colony canal, the first large irrigation works to be built. The farmers under this canal faced a situation which, unless soon relieved, meant their ruin. Unless they could get a share of the river all their crops would scorch under the summer's sun, and even the trees they had planted would die. Yet there was no law by which the upper canals could be compelled to close their headgates, and no officer to enforce such a law had it been in existence. It was another instance of necessity knowing no law. The Greeley farmers shouldered their shotguns and shovels and started upstream. Failing to secure the closing of headgates through appeals or argument, they tore out the dams so that the water flowed down to their farms unobstructed. Agriculture under such conditions ceased to be a peaceful industry. On several occasions bloodshed was narrowly averted, and the feeling between the owners of the upper and lower ditches became so strained that it was plain that there must be some law to govern titles to water if endless litigation or an endless warfare by force was to be averted. It is to the credit of the farmers along this stream that they addressed themselves to the framing of such a law, and gave to Colorado the credit of being the pioneer in placing streams under public control.

In order to do this they had to face a new problem in American civilization, which was to determine the kind of ownership that should be recognized in running water. Up to this time, they had given but little thought to these matters. To the majority of farmers and investors in canals this situation came as a surprise. They had been absorbed in overcoming physical obstacles, in building homes and learning how to supply water to their fields. Doing this was no light undertaking and it had absorbed all their time and energy. Laterals had to be plowed, gopher holes had to be closed, methods of applying water to crops had to be learned, and every day the hot winds blew, fields had to be watered or the desert would resume its sway.

Settlers had to first assure themselves that the experiment they were making was to be a success before it is worth while to provide institutions for its future regulations. Many were doubtful regarding this. Many soon became dissatisfied and surrendered. A letter from one of these homesick, discouraged pioneers illustrates why water laws were not considered until they had to be. Part of it was as follows:

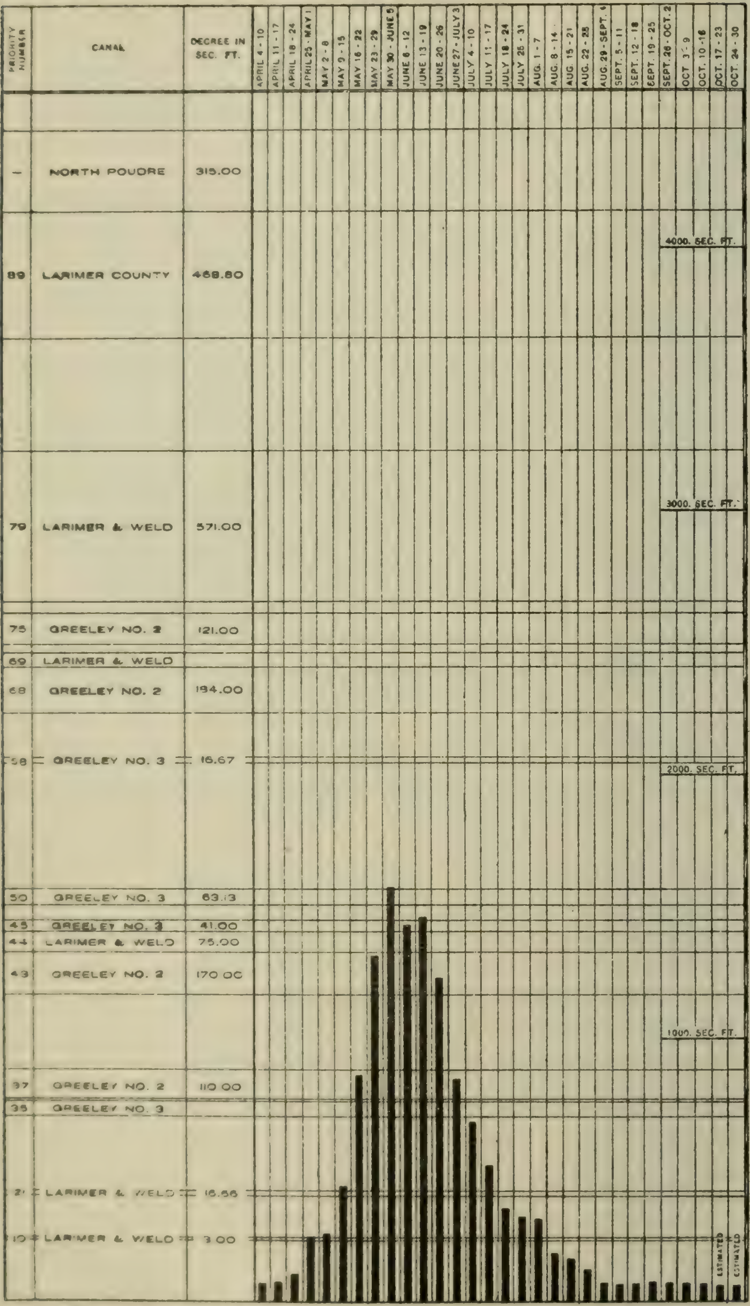
"There is one thing we can and must say to our uneasy, restless readers—don't go to *Greeley, Colorado Territory*. That is the last place on the face of this terrestrial ball that any human being should contemplate removing to. Greeley, Colorado Territoy, is a delusion, a snare, a cheat, a swindle. Greeley, Colorado Territory, is a graveyard, in which are buried heaps of bright hopes and joyous anticipations. Two or three hundred (floating population) that have not 'dudads' enough to get down to Evans, four miles below; several stern-weeel shanties, and a few one-horse tents compose the population of the great Union Colony at Greeley, at the present time. Four hundred of the original colonists have been, looked, got disgusted at, and gone, and the balance will '*ditto*' as soon as their friends send them money enough to do so with. That's Greeley, Colorado Territory.

"Greeley is located—if there be such a thing as locating a baker's dozen slab shanties, as many tool chests, a great ditch and 20 acres of prickly pears—on a barren, sandy plain, part and parcel of the Great American Desert, midway between a poverty-stricken ranch and a prairie-dog village on two sides; and a poverty-stricken ranch and a prairie-dog village on t'other. It is bounded chiefly by prickly pears."

Awakened at last to the need of public control farmers, ditch owners, and a number of able attorneys, devoted much time and study to preparing a plan for establishing rights to the river and for dividing the water supply in times of scarcity. The method finally agreed to required each ditch owner, or appropriator of water, to appear before the district judge and present proof of his right to water. The judge then rendered a decree fixing the amounts of these rights. As the shortage in the stream had shown there was not enough for all, some distinction had to be made between rights in order to know which headgates should be closed in times of scarcity. The first ditch built was given the first right to the stream, and other ditches rights to the remaining water in the order of their construction. Each owner of a right was called an appropriator, using the term "appropriation" in its ordinary sense—to take for one's own. The order of these appropriations was called their priority. The appropriator having the last priority was to be the first cut off when there was a shortage of water, while the holder of the first priority could take the entire stream if he needed it all to supply his right.

When the ditch owners appeared before the court, neither lawyers, witnesses nor the judge had enough practical knowledge of irrigation to bring out the facts. The testimony was given miles away from where the water was used and this encouraged witnesses to use their imagination. No one appeared except those claiming a share of the stream and, as they were all disposed to be liberal to themselves, more water ran through the courthouse than ever flowed in the river. The result would have been grotesque if its consequences had not been so unfortunate. There had been no disinterested measurement of the stream to determine how much water there was to be appropriated, nor impartial gauging of the ditches to show how much had actually been diverted. Although the decree transferred from public to private ownership one of the state's most vital resources, there was no public official at these hearings to look after the public welfare and keep down the rights recognized, to the limits of actual use. The decree gave away over 4,500 cubic feet of water per second, out of a stream which in midsummer often carries less than 100 cubic feet per second, and which has an average discharge of less than 700 cubic feet per second. So far as measurements show, it has never in its highest

U S DEPT. OF AGR.. BUL. 92. OFFICE OF EXPT. STATIONS, IRRIGATION INVESTIGATIONS.



—DIAGRAM SHOWING THE FLOW OF THE CACHE LA POUDRE RIVER FOR THE IRRIGATION SEASON OF 1889 AND THE STAGE AT WHICH CERTAIN CANALS ARE ENTITLED TO WATER.

floods carried the full amount decreed. The decree was most generous to owners of small ditches, one of which irrigating 160 acres was given water enough to cover the land 72 feet deep in one season, while the owners of 20 small ditches were given water enough to cover their lands to a depth of 250 feet in six months. The rights granted some of the large canals were not excessive and, in a few instances, the ditches had diverted more than they were given.

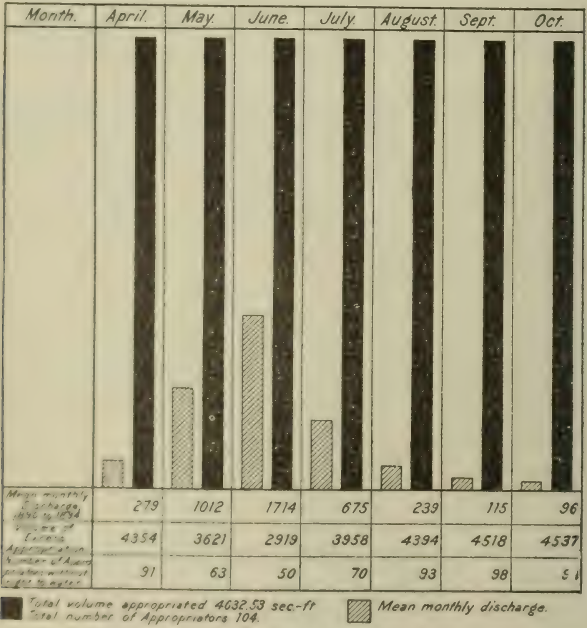
The giving of these rights to the ditches had been strongly objected to by many farmers who believed that they, as the users of the water, should be made the appropriators and that the rights should go to the land rather than to the canals. This plan was defeated because but little of the land was being farmed. The canal companies were represented by able counsel; they had assumed an ownership of the water before the decree was rendered and had been selling rights to farmers based on such ownership, and they wished for the power which the control of the commodity gave. In some instances, the farmers were also ditch owners and the ownership of land, water and means of transportation were all united in the same person, but under the large canals, the water was given to those who were not users but who had acquired it in order to sell to users.

The decree was rendered in 1882. At that time, one of the large canals had not been completed and there was hardly any land cultivated under it. Under two others there were more vacant sections than there were with houses on them. The farmers who were coming in from the east looked carefully at the land but they knew nothing about the value of priorities and all water rights looked alike; hence, settlement went on as rapidly under the ditches with late priorities as those with early ones. Even if settlers had started in to make inquiries, it is doubtful if they would have learned much, because the people themselves did not fully realize the situation. It requires experience to show that a court decree did not increase the flow of the streams and that a paper appropriation, when there was no water back of it, had no more value than a gold brick, even if it had been given an extra gilding by a judicial authority.

In 1884 and 1885 the river was the highest ever known, the water supply was ample, and this gave a breathing spell in which to put the new system in order. It gave time to gauge the canals and prepare tables for the use of the water commissioner, the official whose duty it was to enforce the decree and who had authority to open and close headgates in such a way as to give each appropriator his proper share of the stream. The commissioner had little trouble in these years. He could not give appropriators all that had been decreed them, but he could give farmers all the water they needed.

When the years of normal water supply returned, many of the settlers found that irrigation was no insurance against drouth. Headgates of late appropriators were closed before midsummer, and no drouth in Kansas was ever more severe than prevailed under these canals. Damage suits by the exasperated settlers became common and the companies which had not planned frauds had to set to work in some way to provide the water they had sold. There were two ways of doing this. The earlier ditches were all small and had never been able to use one-tenth of the water given them and they sold the surplus to canal companies which needed it. Transfers of this kind did not, however, increase the irrigated acreage; it simply took the water away from one farmer and gave it to another. In some instances these transfers of priorities robbed orchards that were 20 years old and watered cactus fields which had never been fenced.

When the water commissioner was called to recognize the first of these transfers there was a riot. Men knew that many of the appropriations were excessive, but believed that they were confined to



Relation between the mean monthly discharge of the Poudre River and the appropriations therefrom.

the ditches where acquired, and that, since the owners of these ditches could not use the water, no harm would result. But the sale of these rights to canals with late rights changed the situation, and when the commissioner had an appropriation to be moved upstream ten miles and turned into a late canal, there was such an exhibition of indignant feeling that the commissioner had to resign. For a time the validity of these transfers remained in doubt. Later, the court sustained them, and now they are a part of the recognized order of things.

To irrigate all the land being farmed required an increase in the available water supply, and this could only be secured by building reservoirs to hold back the water which ran to waste before irrigation begins, and to regulate the discharge during the irrigation period, so that when the snows melt too rapidly the water would not run to waste. It was possible to provide water for all the farmers under these canals, although not to give all the water described in the decree. On the Poudre there is too much water in the first half of the year and too little in the last half. The stream begins to rise nearly two months before water is needed by crops, and it falls with startling suddenness in July when the need is greatest.

In the Poudre Valley the need of storage has been increased of late years because of a change in the crops grown. Formerly wheat was the principal product. Its irrigation usually ends in July, but in recent years, potatoes, sugar beets, melons, orchards, and alfalfa have become the leading crops, and all these require watering after mid-summer. These crops have a high acreage value and water for their irrigation commands a higher price and brings a much larger return than when used on land devoted to small grain. Nearly fifty reservoirs have been built to provide for the regulation of this

A Potato Crop near Greeley, Colo.
Irrigated Culture.

stream and between 50 and 100,000 acre-feet of water will be stored this season.

These storage works are filled from existing canals. There was some delay about this at first, because the outlets of these reservoirs are too low to permit of the water being used on the land under the canal which filled them, and it was not until a system of exchanges had been worked out, by which the highest canal turns over the water stored in its reservoirs to those lower down and takes in return the water which the stream carries, that the natural basins that these reservoirs occupy could be utilized. Making these exchanges has, however, greatly increased the labors of the water commissioner. In addition to his division of the stream, he now has to act as an official gauger in the delivery of water from reservoirs to ditches as well as from streams to ditches. Whenever water is turned from a reservoir he has to measure the quantity run out, and to secure greater accuracy in this the legislature has required that an automatic recording instrument shall register the depth of water flowing over a weir.

The reservoirs are filled any time that a surplus exists. If the snows melt, much water is run in in the spring and in early summer. Sometimes a week's rain storm will serve to fill all of them. The general result is that the farmers are able to secure nearly all the water they need. The canal companies are enabled to make their contracts good and the district, as a whole, enjoys a high degree of prosperity, as the following statistics will show:

When the first settlers entered this valley it was a cactus-covered waste. Land could be purchased from the railroads for $1.25 an acre, and water rights sold for $4 an acre. To-day over 25,000 people live within the irrigated district. There are three beet sugar factories, one of which is said to be the largest in the United States. From one railroad station 70,000 cars of potatoes have been shipped in a single year. At another station 175,000 sheep have been fattened in one season from the alfalfa grown under the surrounding ditches. The best land, with a water right attached, sells for $100 an acre. The best water rights are worth $40 per acre without the land and few are for sale.

Summarizing briefly, the administration of this river, we find it to be as follows: The rights to the stream belong to the owners of ditches and are established by decrees of the court. These decrees are largely in excess of both the capacity of ditches to divert water or the river to supply it. Rights to water in the stream are personal property, and are bought and sold like wheat stored in an elevator. The decree of the court represents an ownership in the running water just as a warehouse receipt represents the ownership of grain in the elevator. In his division of the stream the water commissioner pays no attention to how or where the water is used after it passes the headgate. Its subsequent disposal is under the control of the appropriator and his or its customers.

The building of the storage works gave rise to litigation over the priorities of rights to fill reservoirs. The owners of the early priorities attempted to fill the reservoirs under the right acquired for filling their ditches. Those having late rights insist that rights for ditches and reservoirs should be based on the time when the reservoirs were built, rather than on the time when the ditches which filled them were built.

The litigation over this matter has resulted in contradictory decisions, but the indications are that ditch and reservoir rights will be held to be separate from each other, and that there will be two tables of priorities for the water commissioner to look after.

Considering all the circumstances, the results achieved in this district are highly creditable, but the system has dangerous features which should be reformed. The experience of Europe has shown that titles to water and titles to land should be inseparable, and that with each irrigated farm should go a right to water which makes it productive. Nothing can be more dangerous than a divided ownership of land and water. It leads almost inevitably to monopolies in the stream and to the oppression and misery of the tillers of the soil. If the water rights on the Poudre had been given directly to the land irrigated, the needs of this land would have always been a measure of rights and excess decrees would have been impossible. Furthermore, the amount of water controlled would have been diminished with the saturation of the soil and the inauguration of more skillful methods of culture, and this would have left more and more for later appropriators. But under the plan which was followed, those who did not intend to use it have been enabled thereby to levy tribute on those who did. Furthermore, there is no measure by which economy can be enforced or rights restricted to beneficial use. The freedom of transfer, which is recognized, makes it possible for a single individual or corporation to acquire an absolute ownership to the entire river and in this way create a monopoly of an element indispensable to civilized life.

DISCUSSION.

President Finley—I feel that we have all enjoyed Mr. Mead's description of the irrigation of lands, and as for myself I will confess that I had a very hazy idea of just how this was conducted. I would like to ask how they distribute the waters from these canals over the land?

Mr. Mead—The methods of applying the water to the land are furrow irrigation, temporary damming, etc.

Mr. Chas. N. Roberts—I would like to ask what unit of measurement was used.

Mr. Mead—At first the inch was the unit of measurement generally employed. The farmers borrowed it from the miners. The inch is a convenient unit of measurement and is still largely employed by western irrigators. The greatest drawback to the inch is its name. Many farmers do not understand that it is the quantity of water flowing through an orifice under a designated pressure, but determine their inches by measuring the cross-section of the stream, and call that the number of inches delivered without any regard to grade or velocity. The legal unit of measurement in a majority of states is the cubic foot per second. Another unit employed is the acre-foot, which is the amount of water needed to cover an acre of land a foot deep. This is a convenient means of defining the water stored in reservoirs. It is more convenient than the cubic foot because the numbers are not so large.

Mr. Warder—The acre-foot does not introduce the element of time, but I presume the cubic foot necessarily does?

Mr. Mead—It does when applied to running water, but not when applied to stored water.

Mr. Seddon—Is this all under the control of the respective states?

Mr. Mead—All of the irrigation laws are state laws, but in only three states is there complete public supervision.

President Finley—Has not the federal government assumed control?

Mr. Mead—No.

Mr. Seddon—I understood you to say that in one of those streams the irrigation ditches had five feet of water; how wide was it?

Mr. Mead—Sixty feet on top.

President Finley—Considerably more than is obtained on the upper Fox River.

Mr. Mead—Referring to President Finley's inquiry about the federal government assuming control, there was a law passed last winter providing for the construction of irrigation works by the federal government, but that act provides the rights to water shall be established and protected under state laws.

Mr. Seddon—Has anything been done to prevent one state taking water from another? Has the matter ever been adjudicated in the federal courts?

Mr. Mead—Yes, but it has never been finally settled. There are several cases before the courts, and the state of Kansas in a suit against the state of Colorado in the United States Supreme Court has raised all the issues connected with this question.

Mr. Roberts—The Colorado case is still pending?

Mr. Mead—The case has not yet come to trial.

President Finley—If we are going to have the government building works in the states, it might be better for the federal government to have control of the water.

Mr. Seddon—It is earnestly hoped that it will not. Of course it is very proper and desirable that it should contribute the money to build reservoirs and store the water, but the federal government is very slow. It takes thirty years to start a thing and then you can never stop it.

Mr. M. K. Trumbull—A little over a year and a half ago I was in the northern part of Texas. At the time there was a company in that locality constructing a dam and reservoir for irrigation purposes. Those who were furnishing the capital had employed an engineer to help them build the dam, but they paid very little attention to his recommendations. They were in a great hurry to get the dam up and furnish water to the prospective customers. They made no survey and would not allow a survey to be made of the portion of the country to be covered by the water. They had no lines of any kind to determine the location of flumes. This point was near Wichita Falls, and I would like to know if Mr. Mead can throw any light on this particular case. Shortly after I returned from there I saw an account in one of the newspapers that this dam had broken and that the water had flowed over the country and set back the scheme for some time.

Mr. Mead—No, I am not familiar with that case.

Mr. E. D. Miller—I would like to ask what depth you usually use during a season.

Mr. Mead—The water used in a season would cover the ground to a depth of 4¼ feet, measured at the head of the canal.

Mr. Reichman—What is the average amount measured where used?

Mr. Mead—Measured at the margin of the field, it is only about half that measured at the head of the canal.

Mr. Miller—At the field?

Mr. Mead—It runs from 16 to 24 inches, although in some instances enough water is used to cover the land to a depth of ten feet.

Mr. Seddon—Have you a pretty good record of the evaporation?

Mr. Mead—Yes, we have a great many records of evaporation. In the irrigation season they run all the way from two feet to four feet. It is very hard to keep accurate records for twelve months, as it is hard to keep an accurate record in winter. Where these records have been kept they run up to five feet and over in twelve months.

Mr. Roberts—Are concrete lined canals used to any extent?

Mr. Mead—There are a number of canals that have considerable concrete lining. There is a very large amount of concrete work in Utah and there are a number of canals in California cement lined, without any concreting. There is no frost and they just smooth up the earth, coating with cement only about ¼ to ½-inch thick.

Mr. Seddon—What is the difference in loss by seepage between canals with earth bottoms and those lined with cement?

Mr. Mead—The loss in the Gage canal, measured now for three years (the canal is 28 miles long) is less than 2 per cent. It is an open canal but is lined with cement. In an ordinary canal like that the loss is between 40 and 50 per cent of the water.

Mr. Stern, being called on by President Finley, responded as follows:

Mr. Julius Stern—I have no scientific information on the subject at all. What I will say is in regard to a place in southern California, where the elevation is about 2,500 feet, and there I have watched the irrigation works—more particularly of the Little Rock Creek Irrigation District, which was organized under the Wright irrigation act. Measures have just been taken to dissolve this district, but I find that all the irrigation districts that were organized under that act, and which were after the manner of township organizations, placing the voting power in residents as being best whether they owned property or not, proved ineffective; and I think this Little Rock district is the last of them being turned into a private water company. It was found that the irrigation was too expensive, taking pretty much all the proceeds of the crops of the lands. Then the loss by seepage in the open canals, and the evaporation, which in that high altitude is very great, absorbs more than half and sometimes three-quarters of the flow. They have been talking there about putting in pipe systems, but those are very expensive. Of course if they can do that there will be no loss, either from seepage or evaporation, to any appreciable extent, and I presume this will ultimately be done. I think such an investment would be the better one.

The picture shown on the canvas, illustrating the fields under irrigation and the way in which water is let in, is exactly as I have seen it when I was in the west. They have had three years of drought, and the water in Little Rock creek was about all lost, and the ponds became in such condition that about seven-eighths of the cultivators left the country; but now they are trying to organize a private water company and store the water. They have built a large storage reservoir, which I understand has been pretty well filled by the snows and rainfall of last winter—1901 and 1902—and I presume they are now in better condition.

I wish to ask Mr. Mead whether the state of California has taken any steps to provide such supervision as Colorado?

Mr. Mead—No, the commission has just made a report recommending the enactment of the law providing for a board of engineers to act as a board of control, both in collecting records of existing rights and protecting these rights in times of scarcity.

Mr. Stern—Then the measure would be put under state supervision and the state officials would regulate the use of water.

Mr. Seddon—Are the automatic gauges altogether satisfactory?

Mr. Mead—I think so.

Mr. Seddon—That register is full size, is it not?

Mr. Mead—The cylinder is about 10 inches long. It is on the natural scale. If the water level varies more than one foot, the cylinder goes on around.

Formerly nearly all the satisfactory registers came from France. Now they are made in this country cheaper than they can be imported.

Mr. Stern—I would like to ask whether irrigation is in use in France and other foreign countries?

Mr. Mead—Yes, there is considerable irrigation in southern France; also in Algiers. In Italy nearly all the water measurements are through orifices and the use of registers there is not common, while in France the use is common.

President Finley—How much is that land worth an acre now?

Mr. Mead—In the Poudre Valley the good land is worth about $100.00 per acre—sometimes more than that—but throughout the west, irrigated land varies widely in value. In some places you can buy it for $10.00 an acre, and in California I knew of irrigation racts which were sold for $1,800.00 an acre. It depends upon thet products. At high altitudes, where they have frost almost every month, if they irrigate the land it never will have a high value. In places in Wyoming and Idaho you can buy land of that kind for $10.00 an acre with the water right, but where you come into the high-priced orange and lemon lands in southern California, you reach the limit in the other direction. A great deal of that land is worth $1,000.00 to $1,500.00 an acre.

President Finley—My object was to find out, if possible, the added value that irrigation gives to the land.

Mr. Mead—In the Yakima Valley in Washington there is a good illustration of the value of land. The large canal companies there charge $40.00 an acre for water. They will sell a water right to a homestead man for $40.00 an acre.

Mr. Roberts—What country has the most land under irrigation?

Mr. Mead—Colorado and California lead.

Mr. Roberts—Among the states; but I had in mind India and Egypt.

Mr. Mead—This country surpasses Egypt.

President Finley—India leads this country. How does France compare?

Mr. Mead—A very small acreage. Some of the states have considerably more than France.

Mr. Sedden—From your statement I am inclined to think we need irrigation in Illinois.

Mr. Mead—I think there will be a large use of irrigation all through the East.

Mr. Trumbull—Did not congress recently appropriate five or six million dollars to develop irrigation?

Mr. Mead—Congress has set aside the proceeds from the sale of public lands for that purpose.

Mr. Roberts—Is there any work going on under that appropriation now?

Mr. Mead—Nothing but surveys.

President Finley—I should think that the federal government could mix in with that thing to advantage. Is there any regulation in South Dakota around the Black Hills?

Mr. Mead—Do you mean any control?

President Finley—Yes.

Mr. Mead—No; the use of water has not become important enough to make it a serious matter.

ANNUAL MEETING JANUARY 6, 1903

The 487th meeting of the Western Society of Engineers, being the thirty-third annual meeting, was convened in the parlors of the Victoria Hotel, with President W. H. Finley in the chair and about eighty members and guests present.

The meeting was called to order at 7:15 P. M., and, as there were no objections, the minutes of previous meetings and the report of the Board of Direction, which was embodied in the address of retiring President W. H. Finley, were dispensed with, and the Secretary was requested to read the report of the Judgs of the Election:

January 6, 1903.

To the Western Society of Engineers:

The undersigned Judges of Election, having canvassed the ballots cast for the officers of this Society for 1903, have the honor to report as follows:

Total number of ballots received	268
Total number of ballots rejected as irregular	19
Total number of ballots counted	249
Number of votes cast for President:	
Ralph Modjeski	245
G. A. M. Liljencrantz	1
Number of votes cast for First Vice President:	
H. W. Parkhurst	245
Number of votes cast for Second Vice President:	
F. E. Turneaure	242
Number of votes cast for Treasurer:	
Andrews Allen	241
W. M. Hughes	1
Number of votes cast for Trustee:	
B. E. Grant	121
W. M. Hughes	101

Respectfully submitted,

Byron B. Carter,
John L. Hall,
Albert Reichmann,
Judges of Election.

The announcement was then made that Mr. Ralph Modjeski was elected President; Mr. H. W. Parkhurst, First Vice President; Prof. F. E. Turneaure, Second Vice President; Mr. Andrews Allen, Treasurer, and Mr. B. E. Grant, Trustee for three years.

On motion of Mr. Melcher, duly seconded and carried, the reading of other annual reports was dispensed with, and the company adjourned to the dining-room.

After the dinner had been eaten, Mr. W. H. Finley called the meeting to order and presented his address as retiring President. This was virtually the report of the Board of Direction.

ADDRESS OF RETIRING PRESIDENT, MR. W. H. FINLEY.

Gentlemen: This is the Thirty-third Annual Meeting of the Western Society of Engineers, and according to established custom it becomes my duty, as retiring President, to render an account of my stewardship during the past year.

Our membership has shown a gratifying increase during the year, 103 new members having been admitted. Deducting resignations and deaths, the net gain is 80; this is an increase of 14⅓ per cent over the previous year. The total membership of the Society December 31, 1902, was 638, compared with 558 on December 31, 1901.

Our financial condition is equally gratifying. The receipts for the year amounted to $10,690.26, which includes the Octave Chanute medal fund. Deducting this medal fund and interest on investments, leaves a balance of $9,074.26. The expenditures during the year amounted to $8,482.92, which includes $529.54 paid in December, 1901, but rightfully belonging to 1902. We have, therefore, an excess of net receipts over expenditures amounting to $1,191.34, compared with a balance of $387.95 for the preceding year. The total cash assets on December 31, 1902, were $5,100.64, consisting of a mortgage investment of $2,000.00, certificates of deposit for $1,000.00 and $2,100.64 cash in bank. This excellent financial showing is made, despite the fact that we paid more for services than had been paid during any previous year.

Our library is steadily growing in importance, and under the efficient management of the Library Committee shows a decided gain. The total accessions during the year amounted to 322 books, 43 of which were purchased at a cost of $119.00; the remainder were donations and exchanges. We also received 243 pamphlets. Our exchange list amounts to 210 periodicals. I wish to particularly call attention to these exchanges, as they represent the leading journals in all branches of engineering, and I trust the members will in the future make a greater use of them.

My predecessor, in his retiring address, called attention to the crowded condition of the Library, but nothing was done to relieve the condition, for the reason that our lease will expire next May, and it will therefore be the duty of the incoming Board to take the necessary measures to improve the present conditions.

Our Journal has been ably conducted during the year and I think it compares favorably with the publication of any kindred society, and it certainly reflects credit on the Publication Committee and the Secretary, who have worked very hard to keep the Journal up to its standard.

I regret that I am unable to announce the award of medals; the Medal Committee found themselves embarrassed by so many excellent papers and have asked for an extension of time. The award will be announced in the February Journal.

And now, gentlemen, in my parting word to you, I feel inclined to offer some advice. I know that the members take kindly to and profit by advice given on these occasions. Some years ago the incoming President took occasion to speak to the members on things sartorial, and the advice then given has borne fruit, so that each attendant at our annual dinners now reflects the glass of fashion and the mold of form.

My advice is for the members to get better acquainted, and this can only be done by a more generous attendance at our meetings, and our meetings can only be made interesting by having good, live papers. The success of our Journal is also dependent on the class of papers presented for discussion. We are at a disadvantage, compared with the societies and clubs that appoint committees to report on certain subjects. We depend on the voluntary contributions of members.

Gentlemen, when you honored me by an election to the Presidency, you also were thoughtful enough to elect a very efficient Board of Direction, and the associations I have formed in the transaction of the Society's business will always remain a pleasant memory. I wish to thank the members of the Board, and members of the Society generally, for the generous assistance I received.

And now, gentlemen, I come to my last and most pleasing official act—the turning over of the insignia of office to President-elect Modjeski.

ADDRESS OF PRESIDENT-ELECT MODJESKI.

Friends and guests, gentlemen of the Western Society of Engineers: I have no words to express my appreciation of the honor you have conferred on me tonight. I know that, when electing a president, you expect him to do as well as, if not better than, the former President has done. This is absolutely impossible. Mr. Finley has set a pace for performing the duties of President that it is impossible to equal, and certainly is not to be surpassed. He has the rare faculty of being able to be present at several places at the same time, and those gentlemen who served on the Board with me will certify to that fact. All I have to say is, I shall try to do my best, and I thank you again.

I shall now call on Mr. Wallace as the toastmaster of the evening.

ADDRESS OF MR. J. F. WALLACE.

Gentlemen: I am very sorry to say that it has been six years since I have had the honor and the pleasure of addressing you at a banquet. A few days ago a member of your Entertainment Committee called upon me and reminded me of the fact that it had been six years since I attended a meeting of this Society. The years have been busy ones, they have been full years, and it seemed but last night since I had had the pleasure of meeting with the Western Society of Engineers, and while I may have been negligent in my duty, I desire to say that my heart has always been with you.

I am surprised tonight to see so many young faces, which emphasizes the fact that it has been six years since I have met with you. Just a few moments ago there was handed me a communication. It is written on the Lake Shore Limited, it is unsigned, and is poetical. We have only one man, so far as I know, connected with the Western Society of Engineers, who is a poet, and his name is Isham Randolph. Whether Isham Randolph wrote this short poem or not, I am unable to say, but I will try to read it and leave it for you to determine:

"I am loath to miss a banquet,
In the young days of the year,
With its lights aglow and its wit aflow,
And its laughter welling clear.

"I would I were one among you,
As you gather there tonight;
Where friends join hand and comrades stand,
In the strength of manhood's might.

"I would that the call of duty
Had been silent one more day;
For then I, too, had joined with you
And not have been speeding away.

"But though the miles grow many,
And the way so weary and long,
Yet I picture the sight, and am glad tonight,
Of the jest and the far-off song.

"The jest, with its wit and sparkle,
The song with its soulful glee,
There's a charm in the hour of subtle power,
And I fain would remembered be.

"So I send you my word of greeting,
And I pledge you my friendship leal,
As I bid you good cheer for the coming year,
Ye men who are true as steel." (Applause.)

It is needless to tell you that of all the professions, the engineering profession stands at the head. With it, however, go unusual responsibilities. In the law, a lawyer can hang his client and collect his fee, before or afterwards, as the case may be. Excuse me for dropping into anything of that sort—it was not intentional.

A Voice—I believe you wrote that poem.

Mr. Wallace—The doctor can bury his patient and collect his fee from the estate; the minister generally takes up a collection as he goes along, and while he preaches salvation, he does not guarantee it. Even our friend and brother, the architect, can err in his estimates and increase his commission. The engineer, however, if his bridge falls, must bear the responsibility, and is liable to be tried for manslaughter. If his work overruns his estimate, he loses his job. If he does his work quickly and completely, he also loses his job.

The foremost necessity in the engineering profession, however, is a knowledge of law—the law of nature, the law of physics, the statute law, and before he has finished his career he finds it very acceptable to be conversant with laws of several other natures and kinds. Above all things the engineer is orderly and systematic and presumed to be scientific, as you can readily see from the outline and plan that runs through the addresses which we will listen to to-night. One of the singular things about a great many professional men is that frequently they try the professions of others; the engineer tries to perform the functions of a lawyer; frequently the lawyer, as he has done tonight, will undertake the functions of an engineer and make plans for him.

I presume engineers are all familiar with the topography of the State of Illinois, and all know that when the Lord planned to make the Prairie State and cut out a piece to fit it in between the other States, that he had an area that was too large, and the result is that while the central portion of the State is a broad prairie, the edges are crumpled up like the crust of the apple pie that "Mother used to make." In one of the wrinkles in the northwest corner of the State lies a little city imbedded in the hills. The remarkable thing about that little city is the celebrated men that it has turned out. Its name is Galena. From which came statesmen, from which came the greatest warrior the country has produced, from it have come journalists, from it came a mayor who at one time so ably presided over our city and who is with us to-night, and from which has come celebrated lawyers. The name and the associations remind us of the old alchemists who, during the middle ages, tried for centuries to produce gold from lead and the baser metals. In this case the "Great Alchemist" himself produced the men and the characters that have molded our nation. Out of Galena have come many a nuggett of pure gold, not the least of whom is the Honorable Judge Kohlsaat, who will now make our plans for us.

ADDRESS BY JUDGE KOHLSAAT.

"WORKING TO A PLAN."

Mr. Toastmaster and Gentlemen: You can readily see from the highly complimentary introduction given me by your toastmaster that he must be very well acquainted with me. Had he not mentioned it, I should not have done so, for the reason given to ex-Governor Hurd, of Wisconsin, by one of his old soldiers.

One day while sitting in his office at the State House, he became conscious of some one standing in the doorway. Looking up he discovered old Hans, who was a member of his company during the Civil war. At home, before the war, Hans was not held in profound esteem; he was ignorant and rough. Afterward, when war was around him on every hand and death was in the air, Hans found himself a hero. He didn't know what danger was. Like many a hero he shivered himself when the time came. The Governor hastened to him, and, taking his hand, greeted him as an old friend, saying: "I am very glad to see you, Hans, it has been a long time since we met." Hans replied: "And I am proud to see you, Gofner. I am glatt you know me." "Know you," said the Governor, "I'd know you anywhere. I couldn't forget you." "Vell," said Hans, "I told the folks you would know me and they said no." "Well, I am proud to know you, Hans," said the Governor; "you were a brave soldier and I know you." Hans smiled and said: "Gofner, you remember vone nite ven it was cold, you and me vas sleeping unter the same blanket?" "Certainly I do, Hans," said the Governor. "I was glad to do it."

"Vell," said Hans, "if you would like that, Gofner, I haf to ask you dat you don't speak aboud it." "Why not, Hans?" said the Governor. "I recall it with pleasure." "Well, please don't. I would be obliged if you don'd.' "I can't understand, Hans, why I shouldn't speak of it." "Vell," said Hans, "id vas like dis: When people down my vay hear you say, Hans was schleebing mit you vonce, unter the same blanket, den all dare people vants to schleeb mit me." And so I feel, after this warm eulogy and generous admission of regard and friendship on the part of Mr. Wallace, I may be incurring a risk of a similar nature. He makes a good deal of fun of the lawyers. He can afford to do it; but I wish to say in defense of myself that I feel a good deal as an old fellow did down in Connecticut. He was raking up stones in his field just before ploughing time when he overheard two western ladies, who were walking by, saying: "Just see that poor man vainly trying to clear his land of stones. How hard he has to work just to get ready to plough and then what a poor crop he'll have. Out West our ground only has to be tickled with the plough and then it laughs an abundant harvest. Isn't it too bad." He stood it just as long as he could and then broke out with "Ladies, you needn't feel so awfully sorry for me. I only own forty acres of this kind of land." So I don't think I could lay claim to enough of legal learning to warrant the toastmaster's strictness on that account.

It has never been my privilege to meet with your society before this evening. I have never had the opportunity. I have often read of your proceedings and wondered what kind of a society you were. You will pardon me if I pictured to myself a gathering of gray-haired men, with high foreheads, men of vast experience and men who did not look just like the rest of people, and here I come to-night to find around the tables a lot of young men, just the kind of men to make me feel at home at once. So, even if I didn't know Mr. Wallace so awfully well, I should have felt pretty comfortable here to-night in your company. In this great city we don't know much about each other. I perhaps ought to be ashamed to say it, but outside of Mr. Randolph, Mr. Wallace, Gen. Smith and a few others, it has not been my privilege to know of the record you have been making individually. We go through the streets of this great city and see the buildings with no thought of the engineering genius behind their construction; we see the doors, windows, and never for a moment stop to wonder who or what is within them. We read notices of this or that event of the meetings of the Western Society of Engineers without an idea of what it means or how much of brain and skill is there brought together—and so it seems to me it is both proper and wise that men from all the professions and men from commercial pursuits should meet socially so that we may know each other better. Not only that we may understand each other's work, but sometimes we cannot think ill of a man so readily when we know him well.

There are lots of men whom you meet in everyday life of whom you form no opinion at all, but when you are thrown together a month or two, on a vacation, fishing or in some other capacity or entertainment, with such a one whereby you see the good side of that man, he is your friend and you are his friend all your life. Somehow or other there is something underneath these exteriors of ours which we do not see in ordinary contact, but when we are thrown closer together then is discovered that which makes us think of each other. And there is nothing better in life than that which comes to us as we go beneath the exterior, as we go under the crust of life and the affairs of life and the troubles of life and the resistance of life, because these things build a crust about us.

When we get through that there are mighty few people, who are fit to be civil engineers at least, in whom we won't find something to admire and to love, and when we know the man well we love him all our lives, and we won't think any wrong of him. So I say it is a happy thing which brings men of a different profession, as your profession and mine, together on occasions of this sort, to look into each other's faces and read in each other's faces something of that spirit of humanity and love which does not always find expression.

I was rather compelled by your good Secretary to select some sort of a theme the other evening when he spoke to me. He said that the others had all done so, and stated to me what they had chosen for their themes, and so I took one that was left. And really it came to me like this, as he was talking to me, that you men here, being men who do things which can't always be undone, work to a plan. Now, a lawyer does not do that; he can't do it. It is not a necessary part of his profession to follow a particular plan. He has to follow other people's plans. He has to go into your plans; he has to follow merchants' plans. He can't do that without you pencil it out. You lay out your scheme; it looks very simple to the observer, but before you get through there is a whole world of knowledge involved, more than the world knew in its first four or five thousand years. You have to plant the strength of your steel; you have to plan all the principles which govern the building of buildings and the construction of railways, and all those things which come under your care. It involves a world of knowledge. Every step is planned out, one upon another. But you must follow that plan. And I think it is a grand thing. A man who can start with a pencil and make his first mark on the paper and in his mind's eye see some grand structure or some great bridge, to me, who never could, as Mr. Swift knows, make two kite sticks alike, it seems almost marvelous.

You are working always to a plan, and every step of that plan must be just as secure as every other step in that plan. Your building, your structure, is no stronger than its weakest point. Gentlemen, I congratulate you in that you are able to see what must be your duty to-morrow and the day after, and what will be the monument you shall raise to your skill. Yet, with all that, there comes to me this thought, there is a danger of your becoming narrow, danger of your being lost in the following of your plans. Because, adding one to two and two to three is not necessarily broadening. There is a structure going up here about us that is grander than any that you have put pencil upon. It goes without square or trowel or plumb line. It is growing and growing and growing, and, gentlemen, whether you know it or not, whether you see it or not, whether your conscience is aware of it or not, you are adding to the structure. Whether or not we think we are working to an unseen plan, every one of us in all the professions, in every department of life, is working to some plan which requires that you shall go outside of your lines of business, your engineering professions, and give thought, and serious thought, such as a civil engineer can give, to the building up of that temple which is the pride of us all and which is growing into the nation's temple, a temple which hereafter shall stand against the sunlight, with golden dome and minarets and towers. Gentlemen, while you are building and working to your plans do not let it so engross you that you shall for a moment forget your part in the building of this great structure, which must be the hope not only of this great country, but of mankind.

Mr. Wallace—There are some of the older engineers in this country who found that they could get along very well with the strenuous education which they received in the school of adversity, and when they received a diploma from that school they thought they were qualified to practice in later years. The younger men, not being as bright as our older men, have found it necessary to become more thoroughly educated. Of course, education does not supply one with wit or even with everyday common sense, but it does direct him in the better use of the faculties with which God and nature have endowed him. We will now take our first lesson in education to-night from Prof. Howland, of the University of Chicago.

ADDRESS OF PROF. HOWLAND.

"THE NEW EDUCATION."

I appreciate the honor that the Western Society of Engineers has done me in inviting me to be one of its guests. It is getting very near the source of supplies when one is invited to sit down at the table with those very men whose work has made it possible to gather dainties from every land, to have purer water and to have that luxury by which we are surrounded to-night. And it is a pleasant thing when men whose activities run over all the globe are not merely conscious of the existence of a mere stay-at-home in this city, but are willing to have him with them on their festal occasions.

I was asked to say something on a topic of interest to engineers. That is very easy. If I were asked to say something that would certainly be interesting to engineers it would be a more difficult matter, but to speak on a subject in which engineers are interested gives one the whole world to choose from. If one chooses to speak of the progress of science, they know more about it than he does. If one is to speak of the wonderful things in foreign lands, odd customs in strange countries, I have about me here men who have plunged through the jungles of South America, who have gone across every ocean and through the wilds of Asia, who have left in every part of the world the impress of the activity of the American engineer. If I were to speak on some of the problems of government, we have men here who know a good deal more about the way that states are governed and public funds expended and contracts obtained than a university professor. If I take my own special field, that of the study of modern languages, I find that I am entering upon a topic that every one here must know something about; men whose profession takes them to every land must know something of the language of the people among whom they go, and I may say that it is largely due to the common interest of myself and a former president of this society in the Spanish language that I hold my present position at the University of Chicago.

It is difficult, then, to find a topic on which an engineer does not know something equally well, and it is difficult to find a topic on which the engineer does not necessarily know something more than the average man. So I will take up a subject about which he knows something, but not professionally, as I must, and that is the new education.

Socrates, believed by some to have been the wisest man in the world—others think that Solomon, who had seven hundred wives to instruct him, was still wiser—but Socrates considered by many to have been the wisest man in the world, did not believe that a man should spend any of his time in studying the natural sciences, because they had so little to do with a man's mind, they were of so little importance in regard to his soul. What could the movements of the stars or the habits of animals or the study of inorganic matter have to do with man's relations to the Infinite God? Socrates was wise in his generation, but if he could have looked into the future and seen how much even in the study of the soul we have gained from such a practical art as the invention of printing, preserving and widely diffusing the knowledge of the world's great thinkers—if he could have seen how the very nature of the mind and its relations to the body would be studied by the physicians of a later day—if he had realized, a thing that concerns more particularly your own profession, how much the world would gain in every way by ease of communication from land to land, even between lands at that time unknown, but later contributing to the necessities of life—if he could have understood how much could be added to the comfort of human life and how much of importance man might gain by having his way made smoother for him—Socrates would have advised the study of the natural sciences as much as he did advise gymnastics to make the body healthy. He believed that a sound mind existed in a sound body, but he little knew how much, in a future age, might be accomplished for that sound body and sound mind by investigations of whose very nature he could have no suspicion. Problems of drainage, of water supply, of sources of infection, and other countless problems that modern science deals with, concern man's mind as much as his body, from Socrates' own standpoint.

Education in the earliest days was a part of the priestly duty. It was the business of the priest to instruct some man, whom he might leave to take up the priestly work after him. It was the duty of the priests to initiate those whom they believed to be apt pupils not only into their secret belief concerning God, but also into the mysterious rites by which their God was to be propitiated. Education in priestly hands was only slowly extended to the great masses, and then chiefly for religious ends.

At a later date education meant simply gathering about some man who was a teacher and learning all that he had to teach. You remember how President Garfield said that his idea of a college was Mark Hopkins on the other end of a log. In Garfield's day, recent as that was, this was still to a considerable extent true. The personal influence and the example and the words of a great teacher were enough. These two kinds of education still find representatives; the education that is based on man's relation to the church and that based on personal devotion to a leader, whether he be called Socrates or Mark Hopkins or Thomas Arnold. Then education came to be a matter for the State. The secular government took it in hand because of conflict with religious authority or in order to teach the political doctrines of those in power. It was not realized at first that education was a thing to which every citizen had a right, without regard to politics or religion, and a thing which it was the duty of the State to provide as a matter of self-preservation. That idea was reached at length. But only within the most recent years have we come to realize the importance, in education based upon any one of these principles, of training the hand and the eye, as well as the brain, training them all together, and have come to realize the necessity, for that purpose, of great endowments. The university of the present day requirs a vast capital that a university of a hundred years ago would not have known what to do with. A few years ago a man could graduate from a great university with only a little knowledge of Latin and Greek and mathematics, some philosophy and ethics. At the present day a university must have its equipment for chemistry, it must have its equipment for the study of physics, it must have its equipments for the study of the other branches of the natural sciences, and, to have all the completeness necessary, it is necessary also for it to have great wealth.

We sometimes wonder why God permits some things—disasters by fire and flood, apparent injustice, things that we think we could arrange better. We wonder why he permits the accumulation of great wealth in the hands of a few individuals. Well, my old professor of philosophy at college used to be very fond of quoting a certain text of the Bible, "He maketh the wrath of man to praise him and the remainder thereof shall he restrain." Which he interpreted to mean that God can get good out of even what seems to us to be evil. There is no doubt that the work of all our great universities has been made far more beneficial and valuable to the world because of their great endowments, and those endowments have been made possible by the accumulation of wealth in individual hands, as well as by a general increase in the wealth of the world.

And, gentlemen, the credit is largely due to you. If it were not for the means of communication which you have established, the bridging of mighty rivers, the establishing of harbors, the building of railroads, the making possible of great steel structures and of those other things that have so changed the appearance of the world—the wealth of the world would be vastly less. As for the part you have played in the creation of millionaires, perhaps the best excuse is that thus you have made it possible to apply money to the study of science in a way that no other age has seen before. It is seen in the diffusion of libraries and the added wealth and comfort of our great cities, as well as in the gifts constantly made to our colleges and universities, large and small.

One of the things that has been lacking in the University of Chicago has been a School of Engineering. Certain words that President Harper made use of at the last convocation of the university, in December, lead me to believe, without any further inside information, that within a very short time, possibly within a year, the University of Chicago will, through the generosity of men who have the money and who love their great city, and who see the good that will come from it, have this school of engineering. At any rate, it is only a question of time when the University of Chicago will have its school of engineering. Meanwhile our noble state university and our Lewis and Armour Institutes are wisely applying in the same direction the money entrusted to them, and the scientific technical training is recognized in our city and State as the greatest step forward in the new education.

The main difference then between the old education and the new is this, that while the older education was concerned more particularly with the developmnt of man's mind, based upon the idea that the mind and body were separate things, and that nature was still something outside, the present education proceeds on the idea that the mind and the body must be developed together, and that all things contain lessons that are valuable for the development of man's mind. And to reach the highest results we must have gathered together in some way, either through free gifts of individuals, or in what may be perhaps a nobler way, but sometimes less attainable, through the State itself, great endowments, making possible the researches into science that another age did not know.

The first question in the Presbyterian catechism, as you all remember, is, 'What is the chief end of man?" And the answer is, "Man's chief end is to glorify God and enjoy him forever," and the old-school divines thought they were doing that as far as possible when they shut out the natural world and regarded it as the device of the devil. We have got so far now that we believe that the world is the handiwork of God, and we believe the more we know about it and the more we see of it and the deeper we carry our researches into the nature of the world the more capable we are of enjoying God and in that way of rendering him glory.

Gentlemen, I thank you very much for your patience.

Mr. Wallace—When I was a boy on my father's place we used to have an old gentleman to work on Saturdays. The primary object was to have some one to look after us boys and keep us from going fishing. The old gentleman and I became quite well acquainted and we used to criticize each other a great deal. One time I found him whetting his scythe—he used to spend a great deal of time in that way—and I remarked that he spent more time in whetting his scythe than he did in cutting grass. And he said to me: "John, never forget that there is no time lost in whetting." The application I make of this is, that as education sharpens our wits it is whetting, and that as there is no time lost in whetting we can very well remember the old saying that we can't have too much of a good thing, and we will, therefore, call on Prof. Baker, of the University of Illinois, to do some more whetting.

ADDRESS BY PROF. BAKER.

"CONDITIONS NECESSARY FOR INDUSTRIAL PROGRESS."

Mr. Toastmaster and fellow members of the Western Society of Engineers: It gives me pleasure to be here tonight and "whet up," as the toastmaster calls it, by hearing you dis-cuss matters. The work you are engaged in is quite different from that which I am engaged in, and I am glad to come in contact with you and get your views of things.

Mr. Wallace remarked a while ago that some of the older men did not go to school, and were not concerned about whetting in order to become engineers. In a large measure that is true, and in my work I frequently have occasion to refer to the work of our early engineers and to call attention to the brilliant example they have set for younger men. I have long been looking for the opportunity, which Mr. Wallace has given me, to call attention to the need of a carefully prepared biography of some of the men that established precedents in American engineering. They were resolute, self-reliant men, who rightly comprehended the governing conditions and boldly adopted new methods of procedure, which in no small measure enabled our nation to reach its present position of prominence in the industrial world. It is unfortunate that some one who has the ability, and who knows the facts, has not prepared an adequate biographical sketch of these men, that their lives might be an inspiration to those coming after them, and that their achievements may be preserved as an object of pride in the history of American engineering. This suggestion is not on the bill, and therefore I make no charge for it.

I stated that your work and mine are along somewhat different lines, but I have chosen for my topic tonight a part that is common to us all. It is a part of my duty, a part of my business, to think along certain lines, and I ask you to give me a little of your time this evening that you, too, may be led to think along these same lines. I know full well, or I think I do, how busy you are in your own work, and that each day finds you fully occupied; but I fain would ask that you might give a part of your time to the consideration of the erection of that magnificent structure that the eloquent Judge told us of a while ago, that we may help in building up a great nation that will be a blessing to ourselves and those who come after us and a shining light to all the world.

For the past few years our newspapers and our magazines have had much to say about our rapidly increasing foreign trade, chiefly in the way of recording its marvelous growth, but with little attention, so far as I have noticed, to the factors that make such success possible. Of course, such a result depends upon many elements, among which are: (1) The peculiarities of our national ancestry, which has peopled this country with the brightest minds of all nations; (2) our political constitutions, which make it possible for the humblest to rise to the highest position; (3) the fact that we are a great nation, speaking one language, with no barriers in the way of the freest social and commercial intercourse; (4) our great and varied natural resources of mine, forest and soil; (5) the high price of labor, which stimulates the introduction of labor-saving machinery; and (6) the general dissemination of education, which made possible the effective use of labor-saving machinery and permitted the nation to profit by the capable and ambitious workers of all classes.

But we have recently entered upon a new phase of national and industrial life. Until now we have been engaged in subduing the great West, in establishing homes, in founding cities, in building railroads. By legislation we barred out foreign competition and preserved the home market for our own products; but now the new land in the West is occupied and there is no longer an outlet in that quarter for our surplus labor, and our industries have outgrown the home market. If prosperity is to continue in the future as in the past we must have new markets, and in these markets we must meet the competition of the world. What are the conditions necessary for success in that field? The recent commercial history of Germany and Great Britain is significant.

For many generations Great Britain was pre-eminent in manufactures and in commerce. In 1870 she did one-quarter of the world's business, and the English believed that their industrial supremacy was secure; but in a single generation they have waked up to the fact that they are rapidly losing ground and in some respects are already third in the race. With Germany the almost exact reverse is true. Thirty years ago she had a comparatively unimportant place in the commercial world, but in a single generation all this has been changed. The power employed in manufacture has increased four times as rapidly as the population, and the tonnage of the ships engaged in foreign trade has increased tenfold. From 1870 to 1895 German foreign trade increased 42 per cent., while the English increased only 13 per cent.; and from 1895 to 1900 German foreign trade increased $200,000,000, while England's increased only $30,000,000. Why is it that Germany, with one of the poorest seaboards in the world, with a poor soil and with a dangerous military position, has been able in a single generation to outstrip England—the mistress of the sea and the foremost manufacturing nation of the world?

The recent marvelous industrial development of Germany was coincident with, and dependent upon, the development of industrial education. About thirty years ago Germany reorganized and strengthened her technical schools and established many new ones, until now the provision for technical education is the wonder and admiration of all who know the facts. In the number and equipment of her technical schools Germany leads the world. She is fully alive to the commercial importance of scientific investigation and technical education.

England a few years ago, confident in the superiority of her own manufactures, passed a law that all foreign-made goods should be labeled with the name of the country from which they came. This stamp was intended to be a mark of inferiority, but, to the surprise of the British, the label "Made in Germany" appeared on the highest grade of goods, which the Englishman had assumed to be of home manufacture. England received another shock when she awakened and found her street railroads being supplied with electrical apparatus made in America, and when she discovered that her manufacturers were importing American machine tools, and when America obtained the contract for bridges in her African and Indian colonies. After vainly endeavoring to convince herself to the contrary, England is ready to admit that she is being distanced in the industrial and commercial race, because she has not kept alive to the intimate relation between science and industry, and that in neglecting the technical education of her people she has failed to train her industrial army. In these days of sharp competition and small margins, when the entire world is in the market, the nation that most carefully trains its industrial army will gain industrial supremacy. Of course, there are other factors, as wages, labor unions and tariff; but not one of them has such transcendant importance as that training of the individual which enables him to produce the most in the least time and at the smallest cost.

The English now realize that they have made a mistake in failing to recognize the difference between the skilled workman and the technically trained man, and in not providing for the education of the latter. They are now awake to their mistakes in the past and have set about making amends. A technical school has just been opened in Manchester which cost $1,000,000, and two schools have just been established in Ireland, each to cost $500,000, and another is projected for Scotland to cost $750,000, and Birmingham has recently raised $2,000,000 for still another technical school.

What is the lesson for us? It is that if this country is to extend or maintain its foreign trade it must look carefully to higher technical education. We already have a goodly number of technical colleges, but in number and equipment they are inferior to those of Germany, although in method they are better adapted to American conditions than would be the German type. Most of our technical schools are in need of additional equipment and more instructors. Technical education in this country was inaugurated about thirty years ago, and the engineering education given now is vastly better than that of twenty-five years ago; but there is still opportunity for improvement. The one thing necessary is adequate financial support. Technical education, especially engineering education, is very expensive. A large and costly equipment is required, and machines and apparatus wear out or become antiquated and must be replaced by new. Our technical schools need a more generous support, so that they may add to their facilities and extend their courses. Any money given for this purpose is wisely expended, for experience has abundantly proven that money given to technical education is returned many fold in the increased productiveness of the nation's industries. A single example is sufficient. Through scientific investigation and experiment the amount of sugar obtained from a ton of beets in Germany has increased more than twofold in a single generation, and the amount of money that that investigation returns to the nation in a single year is many times the cost of all the scientific investigations carried on in that country during the last thirty years.

To be most effective, technical education must be practically free. Unless it is so many will be debarred from its privileges, and society will be dependent upon a few workers from a favored class. One of the main reasons why this nation has been so prosperous in the past is that education has been free, and consequently the higher ranks have been continually recruited from the lower. The way should be open that the humblest may rise from the lowest to the very highest rank. Education should not be bestowed as a charity, nor as a means for helping the recipient to earn a livelihood, but because the proper education of the people is the only basis for social security, economic prosperity and the highest national development. The conclusion almost certainly follows that only the government has the ability to make provision for the adequate technical education of the people. The Federal Government and the States, particularly the north central ones, have made magnificent provisions for technical education; but the numbers seeking it require increased equipment and the change in industrial life demands a higher grade of work.

At present the engineering college is engaged chiefly in giving the rudiments of an enineering education, but it should do more than simply impart elementary instruction. There are numerous scientific and practical subjects that are very much in need of investigation. The practicing engineer frequently encounters problems which ought to be investigated experimentally, but it is seldom that he can command the necessary laboratory equipment or find the time for such work. There should be some place where such problems could be sent for solution; and where is a better place than a research laboratory established in connection with a technical school? Much of the equipment required in the work of instruction could also be used in research work. The professors now do more or less such work, but they are usually, and rightly, employed because of their ability to teach, and the impartation of instruction consumes so much of their time and energy that they can not do much in the way of investigation. There should be a trained corps of men engaged in original research in matters relating to engineering and manufactures, much as is the case with the agricultural experiments and investigations now being carried on at most agricultural colleges. Many such investigations are returning to the public each year benefits equal to more than hundreds of times their cost. Of these I have only time to mention a few, as the breeding of cotton and of corn, the prevention of smut in oats, and the spraying of apple trees for the destruction of harmful insects. Why should not similar aid be given to our manufacturing interests? Doubtless it would be given if the need were properly presented. Unfortunately, I am able here to-night to offer only a few suggestions.

I refer to the matter here to interest you in the subject, and through you to influence the public to a more liberal support of these public institutions. There are two ways, I think, in which technical education needs help. One is financial aid, to which I have already referred ;and the second is sympathy and co-operation extended to the young men attending these institutions. I recognize that our engineers are the largest body, and the most thoroughly organized and most appreciative of any class intimately related to scientific and technical education. In one respect your appreciation of engineering education is not lacking. I know that you are ready to demand a technical education of those occupying positions under you, whether that position be high or low. In the past twenty-five years there has been a complete revolution in the attitude of practitioners toward the technically trained engineer. Formerly the practicing engineer was skeptical about the value of collegiate training in engineering; but now the demand is almost always for a technical graduate, whatever the position. The public also understands the value of technical training, and as a consequence the engineering colleges of the land are nearly swamped with students. At many of the larger ones the attendance has increased 25 per cent. per year for the last five or six years; but the demand for graduates has been greater than the supply, sometimes two or three times as great. Besides, there are many young men who desire a technical education who lack the money and time to attend a technical institute. This is shown by the marvelous growth in the last ten years of correspondence technical schools. I know of one city down in central Illinois where there is a railroad shop employing three hundred men, of whom seventy-five are faithfully and earnestly carrying on the work of a correspondence technical school.

These facts indicate that we have made great progress in industrial education, at least in engineering education, in the past twenty-five years; but it is this progress and the changed industrial situation that seem to me to warrant us in taking another step forward. It seems to me that we should set in motion forces that will enable us as a nation to make still further progress. Is it too much to ask that opportunity shall be given to the brightest of our young men to extend their technical education still further, and that such sympathy shall be given to their advanced work that they will be inclined to stay at college and continue their research and work of investigation, and thus raise themselves above the general average and possibly become captains of industry who shall help forward the great movements of science and push outward the bounds of human knowledge, that may redound to the industrial advancement of the country?

Will you use your influence as opportunity offers to create a public sentiment favorable to the adequate support of technical education and to the establishment of laboratories for scientific research in matters relating to our engineering and manufacturing interests; and will you offer sympathy and encouragement to the brightest young men to continue their collegiate and scientific training to the greatest possible extent?

Mr. Wallace—We have chosen our profession, laid our plans and received our education. Our next step, at least for modern young men, is to go abroad. When going abroad it is a great deal better to go with somebody who has been there before and who knows where to take us. Some of our younger members may not know that the improvements of the age that we live in are of comparatively recent origin, and that we still have as a member of our society the pioneer in the use of steel constructions, particularly in the use of bridge structures. I refer to the dean of our society, Gen. William Sooy Smith. Before I permit him to arise on his feet I wish to say that he saw some very interesting things in his trip abroad in China and Japan, which he will now tell us about.

ADDRESS BY GEN. WILLIAM SOOY SMITH.

"OBSERVATIONS DURING A RECENT TRIP TO THE ORIENT."

Friends and fellow members of the Western Society of Engineers, I have not been on a junketing expedition this time. I have been abroad, going westward. Once before I started to go around the world—twenty years ago—to learn what I might about the world by such a trip, and I started eastward. I took a whole year for an examination of Europe alone, went through every country in it almost, through almost all of the large iron and steel establishments that seemed worthy of close inspection, and I found that I was going the wrong way. There was nothing in them that I had not seen before, and I concluded that I would go back home and take a rest and the next time I started I would go the other way. And I would advise you, gentlemen, if you should ever propose to go around this globe with advantage, to go westward. That way the star of empire has taken its way, and that way the star of knowledge has also taken its way. Each thing is explained by what you have seen before as you go westward, and the other way it is all a puzzle.

I have recently gone through Japan, Corea and a portion of Manchuria on a business trip, but I put in my time as best I could, and there are a few things of personal interest that I want to say to you this evening.

And, in the first place, do not get the idea that there are no engineers over there on the other side of the Pacific. There are a great many engineers and there are a great many first-class engineers, not only Americans and Europeans, but of the natives themselves. I was brought into close contact with some of the most prominent engineers in the Orient, and I found many of them thoroughly educated and well posted. Take, for instance, Matsumoto, of Japan. He graduated at the Van Renssalaer Polytechnic Institute, at Troy, N. Y., went out to Japan, and, being of a high family, soon got into a fine position and for a great many years has been at the head of the imperial railways of Japan. I had the good fortune to entertain him at my house when he was here and got quite intimate with him, passed many pleasant hours with him on the other side, and questioned him as closely as I could as to what he had been doing in Japan. I found him "up to date" and admirably informed. I also met N. Shiraishe and many others. They are thoroughly educated. They send their brightest young men to this country and to Europe. They have done so for a great many years, and they are thoroughly trained, and some of them remain in this country and Europe until they get a knowledge of practical engineering in a practical way, and then go back home prepared to take high positions.

There is one thing I would strongly advise engineers. Do not go to the Orient without some previous understanding. Do not think there are not engineers, and good engineers, in that part of the world. Another reason is that wages are exceedingly low, as compared with wages here. I think the wages are not more than half as much as in this country. And also, in Japan especially, there is a strong national feeling. They are a people ambitious to do for themselves, and therefore do not depend upon engineers from outside.

When I started East some twenty years ago I saw a great many things to convince me that we were then neck and neck with the best of them in Europe. Upon one occasion, in London, I was questioned by a party of eminent civil engineers something like this: "You have been considerably about our country?" "Oh, yes." "And looked at our engineering works?" "Yes; as well as I could." "Well, won't you be kind enough to give us your impressions?" "Well," said I, "I have recently been up in Yorkshire and walked several miles over one of your lines and crossed a number of your bridges and studied them as well as I could, and didn't think they were as good as our." "Why not?" "Well, they are box and plate girders of 50, 60 and 70 feet spans. You lay your joists transversely on your bridges and often on the flanges of your girders, giving them a tipping effect; on your girders you then spring brick arches from one joist to another, and on top of these arches put from two to three feet of gravel. Will you tell me why you build your floor system in this way? What do you want with the gravel, and what do you want with the arches, except to hold the gravel?" "Well," said they, "how do you do it?" I answered: "In the first place we do not use box or plate girders to any extent; we can cut out a large part of the material the girder contains and leave it just as strong. We build trusses, putting the material in the lines of direction of the strains. We attach our beams to these at the foot of these uprights, at the point of intersection of our braces, and on these beams put the track stringers and lay the track on them." "With the floor all open?" "Why not?" "How do your men cross your bridges?" "Why, we employ sober men and put a running plank on one side of the track and allow the men to walk it, if they don't they can fall off." They laughed, and some of them said, "The Yankee is right." And so the comparison stood at that time. Wherever I looked over their structures —and some of them were admirably built—but nearly everywhere there was a great waste of material. They have now learned to avoid this somewhat.

The circumstances surrounding the American engineer in the beginning were the most favorable possible to develop the true spirit of the engineer, compelling him to do the very best work he can with the least means. We were compelled to economize in every way in order to do that. First was the fact that material was scarce and hard to get and therefore dear, and we had to build our structures on proper lines and in accordance with the strictest requirements of economy. We had to borrow capital, for we had no money to build railroads. The builders of the road, who furnished the money, were very careful to get engineers who could do the most work for the least money. That influence has followed our profession in all its work from the beginning to the present day, and that influence I believe has been more potent than all others to develop in this country a high order of engineering science, of which we may justly be proud.

At the same time, let us recognize the merits of engineers in other countries. Of all things vanity, such as we are liable to, will be the most dangerous to the success of which we now feel that we are justly proud. We have, as a profession, in this country, done our very best to ascertain the laws which govern the substances which we employ. We have analyzed in the most rigorous manner the strains and the different factors which enter into our structures, and we are certainly very far in advance of anything we could boast of ten years ago, and I believe we are neck and neck with the best engineers in the world, if not a little bit ahead. At the same time when we are speaking of these other men, let us remember that these very men have been taught in our schools, have been upon our works and have been educated here, in our methods, and it is not fair to say that they are merely copyists, because in certain instances which I met with during my recent trip in the East, I found that they have not only adopted our methods, but have developed them in some cases and even improved upon them. While over there I happened to fall in with Shiraishe. He had met me in this country, at Havre de Grace, while I was building the Susquehanna bridge at that point. I met him in traveling and we fell into conversation accidentally. I soon discovered he was an engineer and handed him my card. He said, "I have met you before," and he referred back to our meeting at Havre de Grace. Then he told me he was about to build a dry dock at a certain place and was very much puzzled about the plan. He gave me the data and circumstances in detail, and I said, "That is an ideal case for the application of the 'freezing process.'" I explained it to him and was astonished to see how quickly he took hold of it and understood its advantages as applied to the very case he had in hand. That led to correspondence and consultation, and he has gone on and suggested improvements in the applications of it that were different and better than any that we knew before. For instance, in this large excavation he suggested that we should only freeze a portion of it at a time, using the same set of pipes, over and over again, thus saving a heavy expense. So they are not mere copyists, for they have the ability to originate, to adopt the proper methods and to improve on them and discover new processes of their own.

I saw a good deal of work that astonished me. Some of it very old work. Many of you may have seen such work. I never did in my life. I saw a stone wall laid with blocks that were about that large (indicating), and they were laid in diagonal courses, not horizontal. Give this a little thought and you will see that it has advantages. There is no chance of cracking vertically, the loads are distributed by giving the compressive resistances of the stones a diagonal direction. I never saw masonry built that way anywhere else except in the East.

Now in doing work they are very far behind American methods. They employ hand labor, but they have such an abundance of it that you can't wonder. It is cheaper than the best machinery we can employ. They coal a ship quicker and cheaper by hand than we can by the very best machinery. While they work for from $5 to $6 a month and take care of themselves, they do not do near the amount of work that our men do. It takes three or four coolies to do as much as one of our laborers, but even then the labor is very cheap. And if they were to substitute machinery much the larger part of those people would be thrown out of employment and starvation would stare them in the face. They have built first rate ships, from stem to stern. They make all the machinery that goes into them. They man them and they run them as successfully as any other people. The only objection I have to them is that the doors are entirely too low. I continually bumped my head in going through them.

Now, as to the works that are to be done, there is no end of them. Some works as great as the world has ever seen still remain to be done there.

The opening of the Yang Tse Kiang River is a tremendous undertaking. Great harbors have to be built where there are none now. And the railway systems are all in their infancy, but the whole country is developing rapidly. It looks very much like our own country, consisting of mountains, hills and valleys. Much of it fertile, with products very much like our own. I saw a great deal of Indian corn growing there, but it is of an inferior quality.

Now, there is another thing that will retard our operations in that country. It is the very low price of everything. It is a cheap country, wonderfully cheap, and this is a wonderfully dear country. They only buy from us the things that they *must* buy. The only things we export to that country in any great amount are our bread stuffs. Our bread stuffs are in competition with their rice, which keeps the prices down very low. Almost everything else they can produce much cheaper than we can. Therefore, I don't think that we need expect a great commerce with that country. I suppose we will get it gradually, in the course of a great many years. There is nothing could appear more stupid to any one who looks at the country from that side, than the Chinese Exclusion Act. There is a great surplus of labor and the best kind of labor, although their men are not as vigorous as ours. But if men are paid better they will work better. We are short of labor here; there is a conflict here between capital and labor that is becoming more and more troublesome and threatening, and I think none of us can look forward to what must be the status of that conflict without great concern. We, as lovers of this great country (that we heard spoken of so beautifully this evening), every lover of his country, must dread the conflict becoming more and more threatening every year and must use his brains to the best of his ability to discover some way out of that trouble. There is no doubt that the Exclusion Act, instigated first for a very good reason, is now simply maintained through the influence of the labor of this country, to prevent the lowering of wages, which are now away beyond what they ought to be. We know the labor unions control the elections, and the men to be elected must court their favor. That is the bottom of the whole thing and ought to be removed. A broader and a higher understanding of it should be obtained and our conduct should be on a broader and a higher plane. The conduct of our very wealthy people is reaching down to the lower classes, and instead of living simply and economically, there is a strife that is produced by it that pervades the whole of our national life from top to bottom, and we are on that road which the historians all point out as the one that leads to destruction. Almost every great empire that has existed since the beginning of the world to the present time has met with its end because of the luxury of its people. I think that is our greatest danger.

Now, if we could get, under proper limitations, enough of these laborers to do our work, the prices of everything would be brought down, and we would be getting on to the plane of practical common sense, and our prosperity would be permanent.

I have taken more of your time than I should have taken, and I thank you for your attention.

Mr. Wallace: I can't help but wonder what our genius is going to say under his subject. I have heard him so many times, and it may be that he is going to tell us that story about that friend of his who found a corpse and was unexpectedly prevented from making a steak out of it. We will now hear from Captain Hunt.

ADDRESS OF CAPTAIN HUNT.

"THE CONCLUSION OF THE WHOLE MATTER."

Mr. Toastmaster and Gentlemen: Fortunately for me, I have had words given to me and a duty to perform. They are not originally my own, but I adopt them with the greatest of pleasure. You, tonight, in the first speech, heard a glowing tribute paid to our country. We had a fraternal speech made by a distinguished member of a sister profession, and I have been requested to propose to you that we shall show how we reciprocate that feeling by tonight electing Judge Kohlsaat an associate member of our organization. I make that as a motion.

(The motion was duly seconded, put and carried unanimously.)

As your Toastmaster said a few minutes ago, you have often listened to me at these banquets, and I think it was very thoughtful of the committee of arrangements not to promulgate this programme earlier, but keep the fact that I was going to say something until the very last moment, because if you had known it would have been strange to me if any of you had come. Nevertheless, gentlemen, it gives me great pleasure to inflict myself upon you. This night, of all the year, is among the happiest to me. Coming here tonight and celebrating with you the glories of such a year as the society has enjoyed, any one who loves it and has been associated with it, and intimately connected with its affairs, as I have in the past, can't help but consider it one of his happiest evenings.

Such a year as we have had! How proud we ought to be of it, and how it ought to nerve us to support our organization by holding up the hands of our new officers, and thus make the coming year better. Because, at last, no matter how good the officers may be, it rests upon the membership whether their efforts shall be successful.

You have had a good time here, and I know you have enjoyed yourselves, and perhaps you feel like that young man whom I knew years ago, who visited his fiancee, and about 11:30 o'clock she looked down into his eyes and said, "John, I must be getting heavy." "Well," he said, "Mary, you were heavy about an hour ago, but since then my legs haven't had any feeling in them." So now, if I have got you in that paralyzed condition perhaps I can hold you a minute or two longer without adding too much to your agony.

Really, sitting here alongside of my distinguished friend and fellow member, ex-Mayor Swift, and enjoying as we have the pleasures of the table, I feel that perhaps I should have taken the advice that was given to another acquaintance of mine—by the way, Mark Twain appropriated this story the other day, but he put it a little differently from what it really happened, and I am going to tell it correctly. I had a friend who sometimes would forget himself in convivial society and drink too much, and one night a friend of his had an awful time with him, and the next morning while he was trying to eat something for breakfast his friend said to him: "If it makes you so sick, why do you drink so much?" He replied, "I don't know." "Surely you know when you get enough whisky, don't you?" "Of course, I do," said he. "Then why do you keep drinking it?" "Well, you know how it is; you are in company and every fellow drinks, and what can you do, you can't refuse?" "Then when you get that way, why don't you take sarsaparilla?" "Confound it, old man, that's the trouble; when I get that way I can't say sarsaparilla!" It surprised me a little bit that I could say it.

But gentlemen, I am afraid that if I keep talking you will be in the condition of another man that I heard about. This happened right here in Chicago, the week before last when that distinguished foreign actress, Madame Duse, was here. This conversation was overheard in the next row back: "You like her, don't you?" said the lady. "Well I don't know," replied the man. "But don't you find that she grows on you?" "Well, if I did, I would have a surgical operation."

Now, gentlemen, I am not going to stay on my feet long enough for you to call in the surgeons. We have had the lawyers and the professors and the engineers, but we will not have the doctors this evening; that is, if you go right home from here. You have enjoyed them for the words of wisdom and patriotism. You have had a flow of eloquence and good cheer, and I think you are in a condition to go home; and tomorrow ponder over these things which have been laid before you; and we will enter upon our lives as citizens and continue our careers as engineers with better spirit, not forgetting while we are trying to build up our country and institutions and to help mankind, to do so by helping Professor Baker with his educational ideas, which are as sound as sound can be. We will also help to sustain this society, and in doing that we will be making an effort in a direction which will contribute as much as anything we can do, gentlemen, to carry out all these high aims. Thank you, gentlemen.

The meeting then adjourned.

ANNUAL REPORTS.

TREASURER'S REPORT FOR 1902.

To the Board of Direction, Western Society of Engineers, Chicago:

GENTLEMEN: I respectfully submit herewith a statement of the Treasurer's account for the year 1902, as follows:

CASH STATEMENT.

January 1, 1902, Cash (including $2,000.00 certificates of deposit)		$ 2,354.56	
RECEIPTS.			
Chanute fund	$1,025.00		
Dues	5,077.68		
Entrance fees	902.00		
Subscriptions	372.53		
Advertisements	2,470.66		
Journal sales	223.71		
Interest	83.04		
Library account	13.60		
House account	246.10		
Stationery, postage and exchange	.15		
General printing	272.25		
Back advertisements, W. S. E.	12.54	10,699.26	$13,053.82
EXPENDITURES.			
Interest	42.52		
Journal account	3,184.73		
Library account	432.74		
House expense	2,123.82		
Stationery, postage, etc	390.27		
General printing	571.10		
Services Secretary	1,100.00		
Furniture and fixtures	108.00	7,953.18	
Investment		3,000.00	
Cash, December 31, 1902		2,100.64	13,053.82

MEMO. OF INVESTMENTS,

December 31, 1902.

Mortgage, bearing 5 per cent	$2,000.00
Certificates of deposit, 3 per cent	1,000.00
Total investments	$3,000.00

Respectfully,

ANDREWS ALLEN,
Treasurer.

REPORT OF FINANCE COMMITTEE.

CHICAGO, January 6, 1903.

To the Board of Direction, Western Society of Engineers, Chicago:

GENTLEMEN: The Finance Committee respectfully submits the following conservative estimate of the financial condition of the Western Society of Engineers, December 31, 1902:

RESOURCES.			
Cash on hand, subject to check		$2,100.64	
Dues for 1902	$ 147.50		
Entrance fees	30.00		
Subscriptions to Journal	8.00		
Advertising in Journal	544.50		
Journal sales	72.00		
Library sales, book-binding	6.00	808.00	
Investments	3,000.00		
Furniture and fixtures account	648.00		
Stock of Journals (estimated)	600.00		
Books in library (estimated)	3,000.00	7,248.00	$10,156.64
LIABILITIES.			
Bills payable, vouchers for December bills	616.66		
Advance payments received for dues	65.80		
" payments received for subscriptions to Journal	25.20		
" payments for advertisements in Journal	6.00	713.66	
Chanute Medal Fund		1,025.00	
Net resources		8,417.98	10,156.64

Finance Committee,
R. MODJESKI,
ANDREWS ALLEN,
D. ROYSE.

CHICAGO, FEBRUARY 16, 1903.

To the Board of Direction, Western Society of Engineers, Chicago:

GENTLEMEN—The Auditing Committee herewith reports that they have made a careful examination of the books, accounts and vouchers of the Secretary and the Treasurer of the Western Society of Engineers, and find the same to be correct.

They further report that the authorized expenditures were checked by the vouchers signed by the proper officers of the Society, but upon investigation of the authority for said vouchers it was found that the record of minutes of the meetings authorizing expenditures consisted of typewritten reports only, on loose sheets. It is believed that these records as kept at present would not have the permanency or the standing in court that manuscript and signed records in book form would have. Therefore, it is recommended by your Committee that the records be kept in the usual manuscript form, and that they be properly signed by the Secretary.

It is believed that the accounts have been faithfully and accurately kept, but it is found that there is no system in use by the Society which gives a complete check on the receipts of money. Respectfully submitted,

C. F. LOWETH,
B. E. GRANT,
WARREN R. ROBERTS,

RECEIPTS, 1902.

1902.	Dues.	Entrance Fees.	Subscriptions.	Advertisements.	House Expenses	Library Sales.	General Printing.	Interest.	Journal Sales	Medal Fund and Interest.	Stationery Printing & Exch.	Totals.
January	$1,476.68	$ 69.00	$68.50	$ 55.83	$20.00	$ .20	....	....	$ 8.75	....	....	$1,698.96
February	658.85	10.00	98.00	40.00	7.85	5.60	....	....	33.85	....	....	854.15
March	445.00	71.00	50.75	105.50	30.00	.75	$13.50	$23.38	27.86	$1,000.00	....	1,827.74
April	679.70	100.00	11.50	405.50	10.00	.30	....	....	9.20	....	....	1,276.20
May	385.55	62.00	55.70	355.50	7.00	....	....	15.12	10.20	....	....	891.07
June	238.70	103.00	23.00	117.00	35.50	1.25	43.00	....	20.40	....	....	641.85
July	201.15	60.00	10.88	46.00	2.00	....	....	8.29	10.00	....	....	398.32
August	199.50	53.00	8.00	129.00	18.50	....	....	25.00	1.90	25.00	$0.10	460.00
September	214.30	57.00	4.00	266.33	10.00	5.00	45.00	....	14.75	....	....	616.38
October	219.55	80.00	10.00	245.50	22.00	.25	25.00	11.25	11.00	....	.05	624.60
November	95.00	57.00	4.00	416.04	15.00	....	100.00	....	72.40	....	....	760.04
December	203.10	120.00	28.20	181.00	68.25	.25	45.75	....	3.40	....	....	649.95
Totals	$5,077.68	$902.00	$372.53	$2483.20	$246.10	$13.60	$272.25	$83.04	223.71	$1,025.00	$0.15	$10,699.26

Cash on Hand, January 1, 1902.................. 2,354 56

$13,053 82

EXPENDITURES, 1902.

1902.	Secretary, Salary.	Stationery Printing & Exch.	Journal Account.	Library Account.	House Expense Account.	Furniture and Fixtures	General Printing.	Interest.	Investments.	Medal Account.	Totals.	
February	$100.00	$66.70	$391.90	$ 39.90	$294.33	....	$ 26.30	....	....	....	$ 919 13	
March	100.00	32.91	148.09	45.89	179.21	$27.25	39.30	$42.52	$2,000 00	....	2,615.17	
April	100.00	46.50	535.94	26.25	234.37	....	20.20	....	....	....	963.26	
May	100.00	25 28	482.93	30.50	150.29	8.50	46.05	....	500.00	....	1,343.55	
June	100.00	45.05	94.18	23.65	197.76	....	10.00	....	500.00	....	970.64	
July	100.00	23.30	101.72	12.55	143.18	42.00	47.05	....	....	....	469.80	
August	100.00	30.30	298.39	20.40	158.41	....	191.00	....	....	....	798.50	
September	100.00	10.75	371.59	118.40	165.94	15.25	5.90	....	....	....	787.83	
October	100.00	24.85	106.59	53.60	172.11	15.00	39.35	....	....	....	511.50	
November	100.00	28.21	528.78	21.00	193.96	....	87.45	....	....	....	959.40	
December	100.00	56.42	124.62	40.60	234.26	....	58.50	....	....	....	614.40	
Total, 11 months	$1,100 00	$390.27	$3,184.73	$432.74	$2,123.82	$108.00	$571.10	$42.52	$3,000.00	....	10,953.18	$10,953.18
January—Paid December 31, 1902	$100.00	$27.25	$91.18	$72.90	$100.41	....	$37.80	....	....	$100.00	$529.54	
Total 12 months	$1,200.00	$417.52	$3,275.91	$505.64	$2,224.23	$108.00	$608.90	$42.52	$3,000.00	$100.00	11,482.72	

Cash on hand, December 31, 1902................ $2,100.64

$13,053.82

SECRETARY'S REPORT.

January 1, 1903.

To the Board of Direction, Western Society of Engineers, Chicago:

Gentlemen—The increase of membership the past year has been notable, as there were received 117 applications. All of those, however, were not acted upon. There were eight applications from Juniors to be advanced to a higher grade (seven to Active membership and one to Asscociate grade).

The table shows the net increase to have been 80 for the twelve months of 1902, and the total membership today is 638.

	1901.			1902.			Gains.		Losses.		
	Resident.	Non-Resident.	Total.	Resident.	Non-Resident.	Total.	Elected.	Transferred.	Transferred.	Deaths.	Resigned and Dropped.
Honorary	1	...	1	1	....	1	....	....	....	....	....
Active	286	185	471	314	214	528	66	7	....	4	12
Associate	25	3	28	34	5	39	10	1	....	....	....
Junior	27	31	58	37	33	70	27	....	8	1	6
Totals	339	219	558	386	252	638	103	8	8	5	18

There have been five deaths during the year, as follows:
January 7, 1902, M. Lassig, Active member.
January 31, 1902, E. L. Adams, Junior member.
May 29, 1902, E. J. Blake, Active member.
June 23, 1902, Prof. J. B. Johnson, Active member.
August 22, 1902, Augustus Torrey, Active member.

Our membership has been diminished by eighteen resignations and names dropped from the membership list.

There were twenty-six (26) called meetings during the year. This includes the annual meeting, one "smoker," and one joint meeting with the Chicago members of the American Institute of Electrical Engineers. The list also includes three "Ladies' Nights," when illustrated papers of a general character were presented and refreshments served.

There were presented twenty-six (26) papers at our own meetings, of which twenty-three (23) have been printed in the Journal W. S. E. during 1902.

Following is a list of meetings and papers presented:

The 32nd Annual Meeting (No. 461), held January 7, 1902, at the Auditorium Hotel. Report of Election, Dinner and Addresses.

Wednesday Evening, January 15, 1902, Extra Meeting (No. 462).

Mr. P. A. Maignen, of Philadelphia, presented an address on "Water Purification and Filtration."

Wednesday Evening, February 5, 1902, Regular Meeting (No. 463).

Mr. J. W. Alvord, M. W. S. E., presented a paper on "Sewage Purification Plants."

Saturday Evening, February 15, 1902, Extra Meeting (No. 464).

Ladies' Night. Met in Studebaker Building, Assembly Hall. Mr. W. J. Karner, M. W. S. E., gave an illustrated lecture, "From Paris to Brussels."

Wednesday Evening, February 19, 1902, Extra Meeting (No. 465).

Mr. Robert E. Milligan, M. W. S. E., presented a paper on "Mechanical Filtration."

Wednesday Evening, March 5, 1902, Regular Meeting (No. 466).

Mr. Wm. M. Torrance, M. W. S. E., presented a paper on "The Transition Spiral."

Wednesday Evening, March 19, 1902, Extra Meeting (No. 467).

Mr. F. R. Still of Detroit addressed the Society on "Mechanical Draft."

Saturday Evening, March 22, 1902, Extra Meeting (No. 468).

"Smoker."

Wednesday Evening, April 2, 1902, Regular Meeting (No. 469).

Mr. H. W. Parkhurst, M. W. S. E., presented a paper on "Wet, Dry or Medium Concrete."

Wednesday Evening, April 16, 1902, Extra Meeting (No. 470).

A symposium, "Early Engineering in Chicago." Messrs. L. P. Morehouse, L. E. Cooley, G. A. M. Liljencrantz, J. A. Seddon and J. F. Foster of South Parks.

Friday Evening, April 25, 1902, Extra Meeting (No. 471).

Called at invitation of Mr. R. H. Pierce, Local Honorary Secretary, American Institute of Electrical Engineers, to join the Electrical Engineers.

Electric Elevators.

Wednesday Evening, May 7, 1902, Regular Meeting (No. 472).

Prof. S. W. Stratton, Director of National Bureau of Standards, Washington, D. C., addressed the Society on "The Work of the National Bureau of Standards."

Wednesday Evening, May 28, 1902, Extra Meeting (No. 473).

Mr. W. G. Sloan, M. W. S. E., presented a paper on the British Westinghouse Electric & Manufacturing Company's plant near Manchester, Eng.

Ladies invited and present.

Wednesday Evening, June 4, 1902, Regular Meeting (No. 474).

Mr. C. D. Hill, M. W. S. E., presented his paper of "Notes on the Designing of Chicago Sewers."

Wednesday Evening, June 18, 1902, Extra Meeting (No. 475).

"Discussion of the Metric System of Weights and Measures," by Messrs. Eldridge, Tutton, Sanne, Macomber, French, Mann (of Kokomo), F. Sargent, H. P. Boardman, Tratman, Liljencrantz, Finley, B. B. Carter, Trumbull, Milligan, Pratt, H. B. Boardman, Means, Armstrong, Brunner and Van Der Vaart.

Wednesday Evening, July 9, 1902, Extra Meeting (No. 476).

Capt. Chas. C. Jamieson, U. S. N., addressed the Society on "Armor and Ordnance, Projectiles, and Use of High Explosives."

Wednesday Evening, September 3, 1902, Regular Meeting (No. 477).

Mr. W. J. Karner, M. W. S. E., read a paper by Mr. E. L. Corthell, M. W. S. E., on "Engineering in Argentina, S. A."

Ladies' Night.

Wednesday Evening, September 17, 1902, Extra Meeting (No. 478).

Mr. Geo. W. Jackson presented a paper on "The Scope, Extent and Construction of the Underground Conduits of the Illinois Telephone & Telegraph Co., Chicago." Also Messrs. Crook and Keith addressed the Society on "The Automatic Switchboard and Telephone Combined."

Wednesday Evening, October 1, 1902, Regular Meeting (No. 479).

Mr. J. N. Hatch, M. W. S. E., addressed the Society on "Modern Handling of Iron Ore on the Great Lakes."

Thursday Evening, October 16, 1902, Extra Meeting (No. 480).

Held in Fullerton Hall, Art Institute. Mr. Edward Atkinson, of Boston, addressed the society on "Fire Prevention."

Wednesday Evening, October 22, 1902, Extra Meeting (No. 481).

Mr. J. N. Darling, M. W. S. E., presented a paper on "The Yazoo Delta of Mississippi and Location and Construction of its Railroads."

Mr. E. S. Cole, M. W. S. E., presented a paper on "Water Waste in Cities and its Detection."

Wednesday Evening, November 5, 1902, Regular Meeting (No. 482).

Mr. Elwood Mead, of Washington, D. C., addressed the Society on "The Administration of Streams Used in Irrigation."

Wednesday Evening, November 19, 1902, Extra Meeting (No. 483).

Mr. Wm. Musham, Fire Marshal of Chicago, presented a paper on "Fire Extinguishment in Chicago."

Also Mr. E. B. Ellicott, M. W. S. E., presented a paper on "The Transmission of Fire Alarms."

Wednesday Evening, December 3, 1902, Regular Meeting (No. 484).

Mr. J. F. Jackson, M. W. S. E., addressed the Society on "Copper Mining in Upper Michigan."

Wednesday evening, December 10, 1902, Extra Meeting (No. 485).

Capt. W. H. Jacques, of Boston, addressed the Society on "Submarine Navigation and Warfare."

Wednesday Evening, December 17, 1902, Extra Meeting (No. 486).

A paper from Mr. A. A. Schenck, M. W. S. E., was presented on "Diversity of Practice in General Engineering on American Railways."

LIBRARIAN'S REPORT.

January 6, 1902.

To the Library Committee of the Western Society of Engineers, Chicago:

Gentlemen—I respectfully submit the following report on the Library of the Western Society of Engineers:

Total number of books accessioned December 31, 1901......		3,975
Total number of books accessioned December 31, 1902......		4,297
Increase of books in the Library.....................		322
Of these—By purchase (at a cost of $119.00)..........	43	
By gift	168	
By exchange	111	
		322

In addition to the above, 290 valuable pamphlets have been added to the Library. This does not include many trade catalogues and duplicate books and pamphlets.

The Exchange List has been increased since last year and now numbers about 210, as follows:

One tri-weekly paper, 54 weeklies, 7 semi-monthlies, 84 monthlies, 10 bi-monthlies, 22 quarterlies, 6 semi-annuals and 27 annuals.

Some of the semi-annuals and annuals come in bound form ready to be added to the Library. Some other that come more frequently, as monthlies and weeklies, are bound up by the Society and added to the Library.

The charges on the books of the Society on account of the Library, for the year 1902, were......................	$432.74
From which deduct from library sales, bookbinding, etc...	13.60
Leaving a net charge against the Library of......	$419.14

This includes such portion of the salary of the Assistant to the Secretary in proportion to the time expended on library work. It also includes the amount of $119.00 expended during the year for the purchase of forty-three books, as already noted.

During the past year some additional book cases, of the sectional Globe-Wernicke type, with glass fronts, have been added to the reading room, and give some additional much needed shelf room. The cost of these was charged to furniture and fixtures.

Improved lighting in the meeting room has been obtained by enclosing the ceiling lights in hemispherical holophane glass shades.

A speaker's platform has been constructed at one end of the meeting room, which has proved of great advantage.

The question of rooms for the Society's use has to be considered. The lease of our present quarters expires by limitation on May 1st, 1903. Some investigation was made as to other localities, and though the agents for the Monadnock Building state that the rental for our present quarters will be increased 25 per cent after May 1st, and though the rooms are inadequate for our use, it is believed to be to the best interest of the Society to remain a while longer where we are, as suitable quarters do not seem to be available, except at a much greater cost than what the present quarters will cost, even with the advance in rent. A rearrangement of the present rooms is under consideration, which seems to offer some advantages. These consist of transferring the Library and Secretary's office to the north (or reading) room, known as Nos. 1734-5, and moving the reading room to the present library room, known as Nos. 1736-7. Also in cutting a wide opening in the partition now between the Secretary's office (No. 1737) and the meeting room, known as Nos. 1738-41, which would virtually add additional space to the meeting room by means of this wide opening in this partition now between these two rooms. This also involves placing the speaker's platform at the south end of the meeting room next to the partition between Nos. 1741-42. In this connection the seats would be rearranged to face south and preferably in a solid block in the central portion of the room, with narrow passageways along each wall. It would also be very desirable to make a change in the seats. Most of the present supply of chairs are cheap, common ones, and it is believed that new and more comfortable and suitable seats could and should be substituted.

With the rearrangement of the rooms as indicated there would be space for an increase in the size of the book stacks, which would give a much needed increase in the shelf room for the continual increase in the Library.

Very respectfully submitted,

J. H. Warder, Librarian.

ABSTRACT OF MINUTES OF THE SOCIETY.

EXTRA MEETING, January 21, 1903.

A meeting of the Society (No. 488) was held Wednesday, January 21, 1903. The meeting was called to order about 8:20 p. m., with Vice President Parkhurst in the chair and about ninety members and guests present. There was no business brought before the house.

Mr. Parkhurst introduced Mr. G. N. Linday, who gave a talk on "Some Curious Kinds of Lattice Trusses." His remarks were illustrated by six small models, as well as by some lantern slides. It was shown that certain forms of trusses would not carry a load at certain panel points, while others of the same kind, differing only as to the number of panels, were capable of carrying loads applied at any panel point. Discussion followed from Messrs. Armstrong, Horton, Brunner, Swensson, Hatch, Sample, Jacobson, Vent and Parkhurst.

After this Mr. Parkhurst called upon Mr. T. L. Condron for the presentation of his paper—"Specifications for Material and Workmanship for Steel Structures." This paper had already been printed and sent out in advance, but the introductory part was read by the author, and certain parts explained or emphasized. Some lantern slides were employed in illustration. Discussion followed from Messrs. Parkhurst, Brunner, Horton, W. T. Curtis, Sample and Hatch.

The meeting adjourned about 10:50 p. m.

REGULAR MEETING, February 4, 1903.

A regular meeting of the Society (No. 489) was held Wednesday, February 4, and was called to order by 8:15 by President Modjeski. About fifty-five members and guests were present.

A report from the Board of Directors was presented, announcing the election of the following persons into membership in the W. S. E.:

T. A. Bienkinsop, Active.
F. S. Batchelder, Active.
J. V. Rockwell, transfer from Junior to Active.
Chas. C. Whittier, Active.
John O'Gara, Active.
Chas. D. Boyles, Associate.
Robert Kerr, Junior.
E. Lindley Jones, Junior.
Chas. S. Slichter, Active.
Chas. A. Street, Associate.
N. E. Murray, Associate.
E. C. DeWolfe, Active.
Robert B. Campbell, Associate.
Wm. B. Jackson, Active.
Judge C. C. Kohlsaat, Associate.
A. E. Lindau, Active.

Also the following new applications were reported:

Fred L. Thompson, Chicago, Active.
Thos. W. Clayton, Chicago, transfer from Junior to Active.
Alfred G. Dupuis, Chicago, Associate.
Alexander C. Warren, Chicago, transfer from Junior to Active.
James C. Hopkins, Chicago, Active.
Geo. W. Harding, Chicago, Active.
Geo. P. Coleman, Winona, Minn., Active.
R. B. Mildon, Tercio, Colo., Active.

A list of the officers and committees of the W. S. E. for the current year was read by the Secretary.

Announcement was also made of the death of two of our members—Mr. H. E. Stannard and Mr. Carl Binder, and on motion of Mr. S. L. Jacobson, duly carried, the President was requested to appoint a Committee to prepare a Memorial for each of these deceased members.

There being no further business before the Society, Mr. V. R. Lansingh was introduced, who presented a paper on "The Engineering of Illumination." This was illustrated by lantern slides.

A short discussion followed from Messrs. Wolhaupter, Eldridge, Springer, Modjeski and Lansingh.

The meeting adjourned about 10 o'clock.

EXTRA MEETING, February 18, 1903

An extra meeting (No. 490) of the Western Society of Engineers was held February 18, 1903.

Owing to the illness of Mr. T. T. Johnston, M. W. S. E., who had been expected to address the Society on "The Existing High Tension Transmission of Electric Power from Joliet to Chicago, and its Application at the Bridgeport Pumping Station on Ashland Avenue," the meeting was resolved into an informal one.

In the absence of President Modjeski and Vice President Parkhurst, Past President Finley presided, who called the meeting to order at 9:45 and introduced Mr. Wiederhold, of the Philadelphia Asphalt Company, who gave an informal talk on the subject of asphalt and bitumen, the sources of supply and its use for water-proofing of floors, roofs, etc.

The meeting adjourned about 10 p. m., when coffee and sandwiches were served to members and guests present, numbering about sixty.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the issue of the JOURNAL for December, 1902, we have the pleasure to report the following gifts from donors named:

LIST OF NEW BOOKS ADDED TO THE LIBRARY BY PURCHASE.

Sanitary Science, by Sedgwick.
Irrigation in the United States, by F. H. Newell.
Manual of the Steam Engine, by R. H. Thurston.
Manual of Steam Boilers, by R. H. Thurston.
Reservoirs for Irrigation, Water-power and Domestic Water Supply, by James Dix Schuyler.
Purification of Public Water Supplies, by John W. Hill.
Water Filtration Works, by J. H. Fuertes.
Towers and Tanks for Water-Works, by J. N. Hazelhurst.
Development and Transmission of Power, by W. C. Unwin.
Power and Power Transmission, by E. W. Kerr.
Water-power, by Joseph P. Frizell.
Water or Hydraulic Motors, by Philip R. Björling.
Hydraulic Power Engineering, by G. C. Marks.
Sewage and the Bacterial Purification of Sewage, by Rideal.
Sanitary Engineering, by Col. E. C. S. Moore.
Cofferdam Process for Piers, by Chas. E. Fowler.
Design and Construction of Dams, by E. Wegmann.
Portland Cement: Its Manufacture, Testing, Etc., by Butler.
Topographic Surveying, by Herbert M. Wilson.
Applied Mechanics, by Gustano Lanza.

EXCHANGES.

Toronto School of Practical Science, Engineering Society, three pamphlets, Proceedings 1890-1, 1891-2, 1901-2.
Boston Testing Laboratories, four pamphlets, The Metallographist, Vol. V., Nos. 1, 2, 3, 4, 1902.
Brooklyn Engineers' Club, three pamphlets, Proceedings 1898, 1899, 1900.
American Street Railway Association, Chicago, one pamphlet, 21st Annual Report, 1902.
California State Mining Bureau, Lewis E. Aubury, State Mineralogist, two pamphlets, Bulletins Nos. 23 and 24, April and May, 1902.
Smithsonian Institution, one book, cloth, Annual Report, Board of Regents, 1901.
John Crerar Library, one pamphlet, A List of Bibliographies of Special Subjects, July, 1902.
Royal Philosophical Society of Glasgow, 10 pamphlets, Proceedings, Vols. 17 and 21 to 29, inclusive, and Vol. 33, 1885 to date.
Nova-Scotian Institute of Science, one pamphlet, Proceedings, Vol. X., Part 3, Session of 1900-1901.
American Institute of Mining Engineers, one pamphlet, Transactions, Vol. XXI., 1902.
Iowa Engineering Society, one pamphlet, Proceedings of the 14th Annual Meeting, January, 1902.
Ohio Society of Surveyors and Civil Engineers, one pamphlet, 23rd Annual Report, 1902.
Royal Cornwall Polytechnic Society, London, pamphlet, 69th Annual Report, 1901.

New England Cotton Manufacturers' Association, one book, bds., Trans. Semiannual Meeting, September-October, 1902.

A. J. County, Asst. Sec'y, Pennsylvania R. R. Co., one pamphlet, "By-laws and Organization of Phila., Balto. & Washington R. R. Co."

GOVERNMENT PUBLICATIONS AND OTHER BOOKS DONATED TO LIBRARY.

Edward A. Bond, State Engineer and Surveyor, New York, three books, cloth, Reports for 1891, 1892 and 1893.

J. B. Henderson, Queensland, Australia, one book, half cloth and leather, Reports Hydraulic Engineer on Water Supply, 1887. Reports 1895 and 1902, pamphlet form.

Geo. S. Webster, Chief Engineer, Philadelphia Bureau of Surveys, one book, cloth, Third Annual Report, 1901.

Massachusetts State Board of Health, one book, cloth, 33rd Annual Report, 1901.

U. S. Dept. of Agriculture, Section of Foreign Markets, "Our Trade with Scandinavia, 1890-1900." Hitchcock.

U. S. Dept. of Africulture, Bureau of Forestry, Bulletin No. 35, two pamphlets, "Eucalypts Cultivated in the United States."

One pamphlet, "Irrigation from Big Thompson River." Field.

One pamphlet, "Some Typical Reservoirs in the Rocky Mountain States." Mead.

Bulletin No. 36, one pamphlet, "The Woodman's Handbook," Part I. Graves.

Pamphlet, Report of Forester for 1902, by Pinchot.

U. S. War Dept., Reports Military Governor, nine pamphlets.

Annual Reports 1900, Parts 11, 12, 13, on Cuba and Porto Rico.

Chief of Engineers, five volumes, cloth, Report for 1902.

U. S. Geological Survey, Dept. of Interior, Pamphlets:

Bulletin No. 191, North American Geologic Formation Names. Weeks.

Bulletin No. 195, Structural Details in the Green Mountain Region and in Eastern New York. Dale.

Bulletin No. 196, Topographic Development of the Klamath Mountains.

Bulletin No. 197, Origin of Certain Place Names in the United States.

Bulletin No. 198, Berea Grit Oil Sand in the Cadiz Quadrangle, Ohio. Griswold.

Bulletin No. 199, Geology and Water Resources of the Snake River Plains of Idaho. Russell.

Bulletin No. 200, Reconnaissance of the Borax Deposits of Death Valley and Mohave Desert. Campbell.

Bulletin No. 201, Results of Primary Triangulation and Primary Traverse, 1901-2.

Bulletin No. 202, Tests for Gold and Silver in Shales from Western Kansas. Lindgren.

Bulletin No. 203, Bibliography and Index of North American Geology, Paleontology, Petrology and Mineralogy, 1901. Weeks.

Bulletin No. 204, Fossil Flora of the John Day Basin, Oregon. Knowlton.

Two books, cloth, Mineral Resources of the United States, Reports for 1900-1901.

U. S. Coast and Geodetic Survey, List and Catalogue of Publications, 1816-1902. Cloth.

Brooklyn Water Works Association, I. M. de Varona, Chief Engr., one book and eleven pamphlets. Annual Reports 1883 - 1889 and 1892-1896. Dept. City Works.

Two pamphlets, Reports of Dept. of Water Supply, Gas and Electricity, 1st and 2nd Quarter, 1902.

Wisconsin Geological Survey, E. A. Birge, Director, one volume, cloth, Bulletin No. 8, 1902.

City of Buffalo, Department of Public Works, one pamphlet, Annual Report 1901-1902.

Interstate Commerce Commission, E. A. Moseley, Sec'y, one book, cloth, Statistics of Railways in United States, 14th Annual Report, year ending June 30, 1901.

Wm. O. Seymour, Railroad Commisioner, State of Connecticut, one book, cloth, 50th Annual Report, 1902.

City of Boston, one book, cloth, Report Street Dept. for 1901.

John Wiley & Sons, New York, one book, cloth, "Ancient and Modern Engineering and the Isthmian Canal," by W. H. Burr.

Jackson, Geo. W., M. W. S. E., one pamphlet, "Address Delivered Before Chicago Academy of Sciences on Telephone Tunnels, Etc."

Trautwine, Jno. T., one book, leather, new edition "Trautwine's Civil Engineer's Pocket Book."

Warder, R. H., Supt. Lincoln Park, one pamphlet, "The Shore of Lake Michigan," by Edward O. Brown.

Arnold, B. J., M. W. S. E., one pamphlet with accompanying maps, "Chicago Transportation Problem — Engineering and Operating Features," by B. J. Arnold.

Tratman, E. E. R., M. W. S. E.:

3rd and 4th Annual Reports (1897-8) Boston Transit Commission

Report of R. R. & W. Commission, Illinois, 1900.

American Ry. Engineering & M. of W. Assn., 3rd Annual Report, March, 1902, pamphlet.

Assn. of Ry. Supts. of Bridges and Buildings, 10th and 11th Annual Reports, 1900-1, pamphlets.

Report of Survey and Exploration of Northern Ontario, 1900, pamphlet.

Iowa Engineering Society, Report 13th Annual Meeting, Jan. 16-19, 1901, pamphlet.

Indiana Engineering Society, 22nd Annual Meeting, 1902, pamphlet.

Michigan Engineer for 1902, pamphlet.

Connecticut Soc'y of Civil Eng'rs, Report for 1902, pamphlet.

"Jamaica Railway Extension," by Wellington, pamphlet.

Brunner, John, M. W. S. E., seventeen pamphlets:

American Society of Municipal Improvements, Report 8th Annual Convention at Niagara Falls, October, 1901.

U. S Dept. of Agriculture, "Decay of Timber and Methods of Preventing It," by von Schrenk, March, 1902.

"Cement," May, 1900, to November, 1902, inclusive.

Two books, cloth: "Elements of Water Supply Engineering," by Gould, 1899.

"European Cement Industry," by Lewis, 1899.

Love, W. S., M. W. S. E., twelve odd numbers of Engineering News and Engineering Magazine.

Jackman, H. H., one book (silk binding), "General View of Commerce and Industry in the Empire of Japan," Dept. of Agriculture and Commerce, Japan, 1893.

One pamphlet, "Journal of Franklin Institute," March, 1894.

Jacques, William H., Boston, pamphlet, "Solar Generators and Hydraulic Engines."

THE ESTABLISHMENT OF AN ENGINEERING DIRECTORY.

As one of the functions of the Western Society of Engineers is to promote a feeling of comradeship between its members, and to render assistance to them in their professional work, the Board of Direction have decided to establish what, for want of a better term, may be called an Engineering Directory. The object of this is to bring together those members who may be on the outlook for an engagement and those who desire the services of engineers. It is proposed to do this without cost to the members in the way of charges, fees, etc

The name of the applicant for position will be kept privately by the Secretary and not given out, except as provided for in the rules, and every endeavor will be made not only to render real assistance to those members of the Western Society of Engineers who are out of employment, or who may be in search of more congenial positions, but to render such assistance in the right way.

Attention of employers of engineers, whether members or not, is also called to the exceptional value of this bureau to parties desiring engineering services of the highest order.

Rules to Govern the Conduct of this Directory.

First. Blank applications for employment will be given to any member of the Western Society of Engineers or forwarded to him on receipt of request, accompanied by a self-addressed stamped envelope.

Second. When returned to the Secretary, these applications shall be numbered for identification, and posted on a public file in the rooms of the Society. The name and address of applicant shall be kept on the detached coupon on a private file, numbered the same as the application, and will not be given out except to bona fide employers, and then only when in the judgment of the Secretary no confidence is violated in so doing.

Third. Applications from employers of engineers will be placed on a similar public file, and notifications will be sent to all applicants meeting the required conditions, or to any applicant specially designated by prospective employer.

Fourth. Applications, whether of employers or those seeking employment, shall be kept on file for the two calendar months succeeding the date of appication, and then taken off and destroyed. A brief abstract of each application, identified by number only, and stating character of position sought and salary expected, will be published in the JOURNAL. Any letters addressed to file numbers in care of the Secretary will be forwarded to destination.

Fifth. Applications may be kept on file for a longer period than two months if desired by the applicant, who shall notify the Secretary to this effect by postal card or otherwise. Applicants are also requested to notify the Secretary promptly when the application is to be taken off the file.

It is to be hoped that this arrangement of applications, etc., filed at the offices of the Society, will result in benefit to those members who are seeking a professional engagement.

BY ORDER OF THE BOARD OF DIRECTION.

J. H. WARDER, Secretary.

August 5, 1902.

ABSTRACT OF APPLICATIONS FOR EMPLOYMENT.

No. 11—Dec. 8, 1902.

Position Desired.—Engineering or contracting for structural bridge work. Chief engineer or chief draughtsman with manufacturing company preferred.

Experience.—Graduate as C. E. in 1889, and since then engaged in the manufacture or contracting for structural steel or bridge work. Had eight years experience in charge of all engineering and contracting for a bridge company.

No. 12—Jan. 12, 1903.

Position Desired.—Designing, inspection, supervision of construction bridge and structural iron work, and general railway structures.

Experience.—Graduate engineering school. Eighteen years experience with bridge work; six years in consulting engineer's office, and twelve years with three large railway systems

No. 13—Feb. 16, 1903.

Position Desired.—Engineer in charge of structural steel work, design and detail work, or chief draughtsman in charge of office.

Experience.—Graduate of technical university, 1892. Important work in office work and on construction of bridge and building work. Now hold position as chief draughtsman.

No. 14—Feb. 27, 1903.

Position Desired.—Railroad work (maintenance or construction), or with contracting or manufacturing firm.

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CLXVI.

THE ENGINEERING OF ILLUMINATION.

By Van Rensselaer Lansingh.

Read February 4, 1903.

There is, perhaps, no equally important branch of engineering to-day on which as little study has been given as that of scientific illumination. Its importance is so evident that this state of affairs is rather to be wondered at. It is safe to say that 25 per cent of all the light used in this country is wasted, and in the majority of cases, this waste, which would not be tolerated for an instant in any other department, can be saved by a proper consideration of the exact requirements. The customer gladly pays a round percentage increase for his installation in order to obtain a few per cent increase in the efficiency of his machinery, but once having obtained the light, there is as a rule a gross neglect of its utilization. There has been more or less of an extensive awakening to this peculiar condition, and the work of such men as Mr. W. D'A Ryan, Dr. Louis Bell, Prof. Wm. L. Smith and others, shows that this subject is beginning to attract the attention it deserves.

The question of illumination can be divided into three general classes: (A) street and exterior lighting, (B) interior lighting, (C) decorative and scenic lighting. The object of this paper is to point out a few of the underlying principles in interior illumination, with special reference to buildings or rooms of a public or a semi-public character. Before going further it may be well to examine into the factors constituting good illumination. These can be roughly divided into four classes: (1) Steadiness, (2) Diffusion, (3) Quality and (4) Distribution.

STEADINESS.

Lack of steadiness in an illuminant is at once recognized by everybody as undesirable, and modern sources of light are in this respect very good. With the exception of the open gas flame and arcs of low frequency the illuminants themselves are good, although the wandering of an arc lamp and its constant flickering are often objectionable, even with the best of enclosed arcs. There are cases, however, where the use of a reflector often produces the same effect. Any person who has worked for some time under a swinging incandescent lamp, covered by a porcelain or tin reflector, will have noted the fatigue of the eyes, due to the bright streaks on the paper, which are inherent in the incandescent lamp and intensified by the reflector. In fact an office so lighted, unless it is superimposed on a good general illumination, is a fine example of something to be avoided, and will quickly ruin all but the strongest eyes.

DIFFUSION.

Perhaps the first canon of good lighting is to place the illuminant out of the field of vision, or where this is impossible, to so shade it that its intensity is much reduced. The tendency of modern illuminants has been towards high intrinsic brilliancy, so that the following table in this connection, taken from different authorities, is not only of interest but of much importance in the consideration of good lighting,

TABLE OF INTENSITIES IN CANDLE POWER PER SQUARE INCH.

Candle	3	to	4.	
Oil lamp	3	to	8.	
Mantle burner	20	to	25.	
Acetylene	75	to	120.	
Enclosed arc	100	to	200.	(Depending on globe used.)
Incandescent lamp,	100	to	300.	(Depending on efficiency.)
Nernst lamp (bare)	800	to	1,000.	
Open arc	10,000	to	100,000.	
Sun on the horizon	2,000.			
Sun in zenith	190,000.			

The three most common illuminants, arcs, incandescents and mantle burners, show an intensity so much higher than that to which the eye has been trained for centuries, that the use of such illuminants without proper diffusion, has to a very large extent caused the increased use of glasses. It should be noted, however, that the intensity alone is not the only criterion as regards the injurious effect on the eyes. Quantity of light, i. e., the intensity multiplied by the area of the illuminant, is extremely important. Thus, although the intensity of the incandescent lamp is very much higher than the ordinary mantle burner, the effect of the latter on the eyes, unshaded, is perhaps even more injurious than the bare incandescent, owing to the fact that the area of the illuminant is very much larger. The unusual amount of green rays in the mantle burner also plays some part in this connection. The intensity and quantity, therefore, of modern illuminants are not only much too strong for comfort to the eyes, but when the light is in the field of vision, the eye accommodates itself, as far as possible, to the light itself, and is unable to properly judge of objects of less brilliancy. This accounts for the fact that the eye is unable to see past a brilliant light, when it lies in the field of vision. If, however, the light is cut down in intensity by properly diffusing it, the eye can at once see objects beyond the light with comparative ease.

To see how little this important principle is appreciated by the ordinary users of light, one has only to note the glaring examples on any of our streets at night. Here is a store with a row of bright incandescent lights running up and down, as well as across the windows. The lights may attract attention from a distance, but the goods displayed are at the best but poorly illuminated, as far as the eye can judge. There may be plenty of light thrown on the goods, but the diaphragm of the eye accommodates itself to the brilliancy of the lights, and is therefore unable to properly judge of the goods displayed. Next door there may be a store where all the lights are concealed, but by proper reflectors the goods are beautifully illuminated, with perhaps one-half the candle power. The actual illumination on the goods may be considerably less than in the other case, but the eye, not being blinded by the lights themselves, easily accommodates itself to the illuminated goods. One of the worst offenders in this respect is the mantle lamp. A large proportion of those in use are equipped with a little white porcelain fluted reflector, leaving the bare mantle painfully visible. As the candle power of such burners runs from 50 to 500 or more (cluster lamps) the evil effects of such on the eyes can hardly be over-estimated.

In general it is much better to either place the light out of the field of vision, or when this is impossible to use some sort of a diffusing shade, as the chances are that the illumination, i. e., the amount of reflected light falling on the retina of the eye will be greater, for the eye can then work with a larger aperture.

It is also a common mistake to think that the more light one has the better one can see. In fact there can hardly be a greater error. After the stimulation of the retina amounts to a given quantity, the effect of more light is to contract the iris, producing a strain of the muscles of the eye; further, too much light strains the retina, producing after images and rapidly weakening it through over stimulation. The effect is very much like a photographic plate which has been over-exposed; the picture is blurred and darkened. Moreover, too much light entering the eye, whether direct or indirect, prevents one from properly judging of distances and shadows, without which ability to judge, the eye is quickly fatigued.

Where there is insufficient illumination, one of the first phenomena noted is the inability of the eye to judge of color, everything tending to become a dull gray. The muscles of the eye are strained to keep the diaphragm wide open while the eye loses its judgment as to shadows and distances. Moreover, the attention of the observer is strained in an attempt to see properly. The result of too much or too little illumination is in either case apt to be severe and frequent headaches and a final resort to the oculist. It is evident then that we must not err upon either side, i. e., from over or under stimnlation.

It is necessary here to consider briefly certain classes of shades, as these play an important part in laying out any system of lighting. In general, shades can be divided into four classes: (1) Decorative, (2) Diffusing, (3) Directing, (4) Diffusing and Directing. From an engineering standpoint, it is unnecessary here to consider the first class. The second class is extremely important, and there are many kinds on the market which more or less accomplish the work for which they are designed. They all have, however, the objection that they are inefficient, absorbing an amount of light varying from 15 to as high as 60 per cent. The diffusion is often obtained in such shades by coloring matter, and this, as we shall see later, is sometimes highly objectionable. The third class is exemplified by the numerous reflectors on the market. These are, in general, quite efficient as far as concentrating the light in some given direction is concerned, although the actual efficiency, taking into account the spherical distribution, is generally quite low, if the reflector covers a considerable portion of the light. Their chief objection is that they do not diffuse the light, and when used over books, etc., are apt to cast a very strong regular reflection to the eye, which coming as it does from below (the eye is accustomed to have light come from above) produces fatigue very rapidly. An exaggerated case like this is what is known as "snowblindness." It is due to the fact that the strong reflected light is directed to the upper part of the retina, which not being accustomed to this unwonted stimulation, is quickly fatigued.

The fourth class contains such shades as the McCreary, McFadden and Holophane. The first two consist essentially of a reflector with a ground glass bottom, and beautifully accomplish the purpose of throwing a concentrated beam of light without the glare from an ordinary reflector, but at a rather high loss of efficiency, viz: about 34 per cent. For desk lighting these shades are excellent and much to be preferred to the ordinary green porcelain cone with its intensified streaks and its resultant glare, due largely to regular reflection. The Holophane type of shade is an attempt to obtain both diffusion and direction of the rays of light with minimum absorption. Prof. Wm. L. Smith, who has made extensive tests on these and other globes, reports for electrics a mean loss by absorption of $12\frac{3}{10}$ per cent. As these globes play an important part in the exact calculation of illumination, it may be well to examine briefly into the principles of the same. They have a series of annular compound prisms on the external surface, a cross-section of which is shown in Figure 1. As will be seen, those rays, the direction of which it is desired to change by but a small amount such as A A′ are bent by refraction only. Where, however, it is desired to bend the ray still more, advantage is taken of the principle of total reflection shown in D D′. It will be seen at once that by properly shaping these refracting and reflecting surfaces, almost any distribution of light can be obtained.

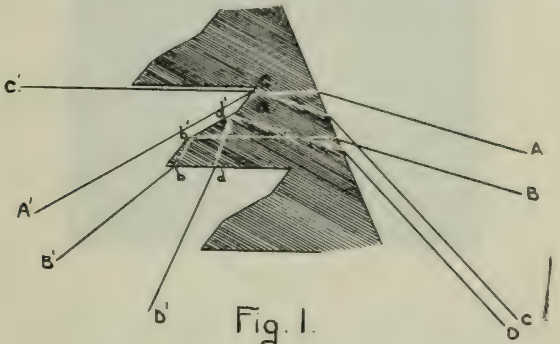


Fig. 1.

In order to obtain the diffusion, the inner surface of the globe is made with a series of vertical prisms, an enlarged cross-section of which is shown in Figure 2. These prisms in general follow the law of cosines, and, as will be seen, split the ray A B into two components, one being simply refracted, while the other is reflected and then refracted. It is evident, however, that such rays as M N and L K striking at right angles to the surface of the glass would not be affected, and the glass would consequently consist of a series

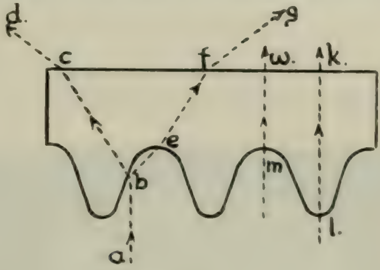


Fig. 2.

of bright streaks. As, however, the exterior prisms are at right angles to the interior prisms, these streaks are broken up, producing a somewhat tessellated appearance, when closely examined, but

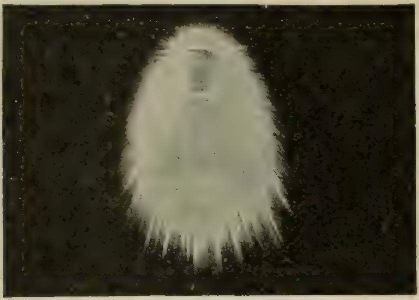


Fig. 3.

in general unnoticed. The perfect diffusion of these globes is only exceeded by a dense opal shade, while their ability to redirect the

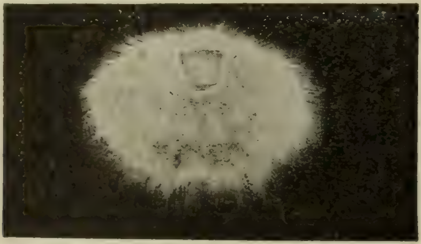


Fig. 4.

rays of light, combined with an absorption factor only slightly higher than clear glass, renders their use in many cases of much value.

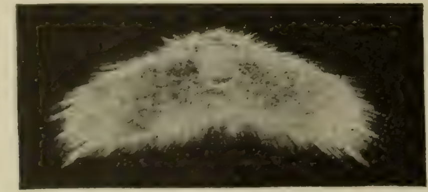
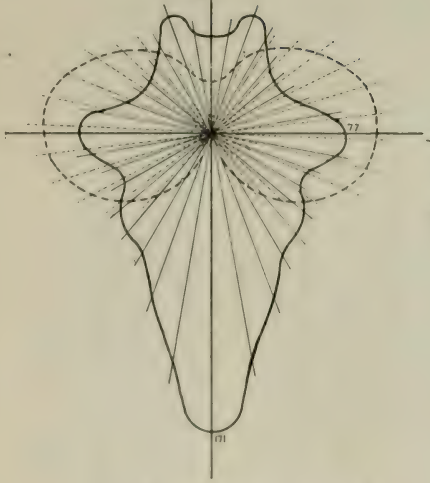


Fig. 5.

Although these globes are made in many shapes and for all forms of illuminants, they can be in general divided into three classes depending on the way they distribute the light. These are rather strikingly illustrated in Figures 3, 4 and 5. Figure 3 shows a type

Photometric Curve

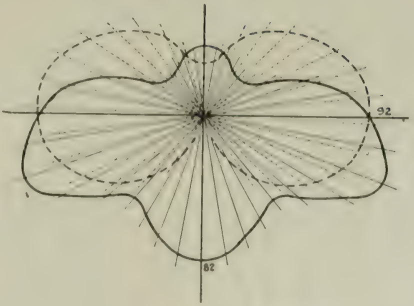
Fig 6



Bare Weisbach - dashed line
With class A Holophane - full line

Photometric Curve

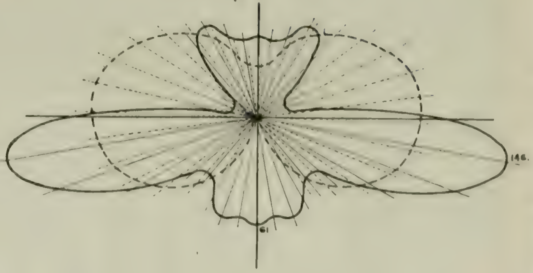
Fig. 7.



Bare Welsbach - dashed line
With class B Holophane - full line

Photometric Curve

Fig. 8.



Bare Welsbach - dashed line
With class C Holophane - full line

Note Dashed line denotes Welsbach
Full " " " with Holophane

of globe for downward distribution, such as is used on high ceilings, over desks, tables, etc. Figure 4 shows a type intended for general distribution, the light being thrown almost equally at all angles below the horizontal. Figure 5 shows a type in which the light is mostly thrown at an angle of from 10 to 20 degrees below the horizontal, and is especially used for lighting large interiors and street lighting. It is rather interesting to note how closely these pictures are actually substantiated by photometric tests, and Figures 6, 7 and 8 show the distribution curves of these globes when applied to the Welsbach light. For the sake of comparison, the curve of the unshaded lamp is also shown by a broken line.

As would naturally be supposed the external horizontal prisms offer a very good place for accumulation of dust, and therefore, unless globes are properly protected, their use outdoors is not to be recommended. In spite of this trouble, the third type of Holophane globes has been used considerably abroad for street lighting. In Munich several thousand have been used on the Welsbach street lamps for several years with extremely good results. As the lights are properly protected by an enclosing lantern, the globes are largely sheltered from the dust. The breakage runs in this installation about 10 per cent per annum. In indoor lighting where the globes can be given proper attention, their use is very important and enable exact calculations to be made beforehand. As the globes are made of pressed glass, individual globes of the same type are practically uniform and allow of precision in the determination beforehand of the results to be obtained; such precision being unattainable with ordinary globes of blown glass, which vary widely in thickness of glass, density and amount of coloring matter. An example of the precision which can be obtained with these globes is the illumination of a church by Prof. Smith. The illumination at 83 points of the church both on the balconies, on the main floor and under the balconies was calculated beforehand and later measured by an illuminometer. The mean per cent between the measured and calculated values was $6\frac{6}{10}$, the maximum being $27\frac{2}{10}$ and the minimum 0.0, the higher figures being due to certain lights which were added after the calculations were made. These results show what it is possible to do in the way of exact calculation of illumination.

QUALITY.

It is well known that modern illuminants vary widely in their proportion of different wave lengths, and that consequently the color effects are very different. We can note here the predominant color in a few of the most important illuminants:

Sun at noon—white.
Sun near sunset—reddish.

Enclosed arc, low voltage—white.
Open arc—bluish white to violet.
Nernst lamp—white.
Acetylene—white.
Incandescent electric—yellowish white.
Mantle burner—white with a tinge of green.
Open flame gas—orange white.
Kerosene lamp—orange white.
Candle—orange yellow.

The question of color plays an important part in the study of illumination. For some purposes, where it is desired to produce the effects of daylight as nearly as possible, the arc lamp, when the violet rays are properly filtered out, plays an important part. In general, however, the color of the arc is cold, and for a room where the effect is to produce a cheerful and warm appearance, an illuminant with more of the red rays, such as the incandescent lamp or ordinary gas, is very much to be preferred. This is well recognized by billiard experts so that daylight is excluded as far as possible and incandescents, not arcs, are used for illumination, giving a warm and cheerful appearance to the room. Candles and oil lamps also produce this effect so that for home use they are from this standpoint, as well as from their low intrinsic brilliancy, preferable to mantle burners or even incandescents.

Recent experiments by Dr. Finsen and others seem to show also that the violet and ultra violet rays are physiologically injurious. If all of these rays are filtered out it has been conclusively shown that smallpox patients are unmarked by the disease. A superabundance of these rays have the effect of destroying bacilli, so that skin diseases and diseases of the tissues are cured by treating the patient to concentrated beams of highly violet and ultra violet rays. Professors Nichols and Hull proved recently by experiment that rays of light are capable of producing pressure and it may be that waves of too high a frequency produce on a delicate tissue too high a concentrated pressure, tending to destroy the same, or at least producing irritation. This would account for the fact that animals as well as persons like the *warm* sunlight or light where the lower part of the spectrum predominates. Thus the harsh effects of brilliant noonday sun, where the waves of higher frequency are not filtered out by the atmosphere are not as pleasant as the warm glow from the setting sun.

Where it is necessary to match colors under an artificial light, too much care cannot be given to the subject of the color of the light and also of surrounding objects. If, for example, it is desired to match a piece of silk, which is blue in daylight, and the same were done in a room where the light was red, the color of the silk would appear almost black. This, however, is an extreme case, as almost all illuminants contain more or less of all wave lengths. As the spectra of artificial illuminants differ considerably from that of daylight, which is taken as a standard, the resultant shade or tints of objects viewed in this light may be considerably altered.

It is, however, necessary to consider not only the color of the illuminants themselves, but also the color of the surrounding objects, as the light is materially affected thereby. When white light falls on a red surface, all the rays except the red ones are absorbed, the red being reflected and we say the object is red. Thus light from such an object consists of red rays, and consequently if the illuminant itself is hidden, we have only red rays, and any object in this light, if not capable of reflecting such, will appear black. It can, therefore, be seen that the color of surrounding objects much affects the character of the illumination.

The amount of light reflected from surfaces is largely dependent on the condition and color of such surface. It is very necessary in calculations, where the walls or decorations play any part to know the character of the same; thus white paper reflects from 70 to 80 per cent; yellow wall paper gives only about half that amount; emerald green about 18 per cent; black paper about 5 per cent, deep blue paper about 3 per cent, while black velvet gives only about $\frac{4}{10}$ of 1 per cent. As these coefficients of diffuse reflections play an important part, as we shall see later, in all attempts at calculation, it is necessary, in order to do the best work, to know rather closely the character of the decorations. A striking example of this was noted by the writer in a club, where one of the main rooms was formerly decorated in light tints. In redecorating, everything was changed to a deep rich red, and while the effect was extremely warm and pleasing, the effective illumination was so cut down, as to make imperative an increase in candle power of the lamps used. One can note this very strikingly if in a dining room decorated in rather dark colors the table is covered by a white cloth, the effect being to brighten the room very noticeably.

It can easily be shown that if K is the coefficient of reflection, and the light is reflected from one wall to the other and back again, the illumination as directly calculated should be multiplied by the factor $\frac{1}{1-K}$ showing the relative effect of the walls. If the room is of any considerable size, this factor becomes in many cases practically unity, while if the decorations are light, this factor may rise to 2 or 3 or even higher, depending on the conditions. It is, therefore, necessary to carefully consider this factor. In the case before mentioned of the calculations of the church, this factor was 75

Photometric & Distribution Curve of 12" Holophane Hemisphere
No 1202 mounted in holder 3-16 c.p. nominal
49 cp actual

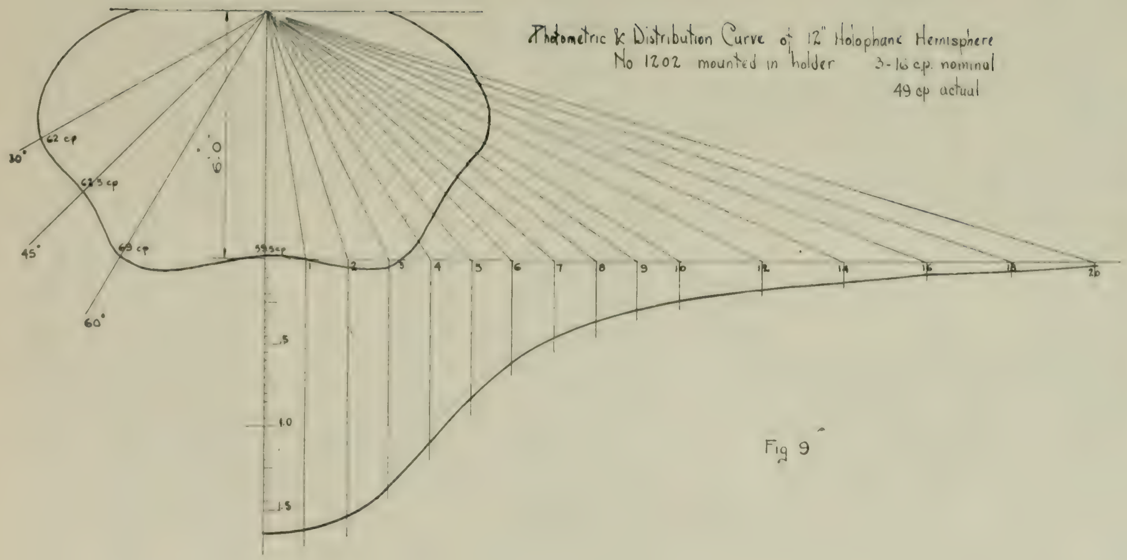


Fig 9

$I_H = \frac{cp \cos^3 \Phi}{h^2}$

Dist.	Φ	cos³Φ	c.p.	H_I
0	0	1.000	59.5	1.650
1	9	.963	61	1.630
2	18	.860	65	1.550
3	26	.726	68.5	1.380
4	33	.590	67	1 095
5	39	.469	64	835
6	45	353	62	608
7	49	.282	61	.478
8	52.5	225	61	.381
9	56	175	61	.296
10	58.5	143	61.5	.244
12	63	.0936	60	.156
14	66	0671	58.5	.108
16	69	0460	56.5	0723
18	71	0345	54	.0518
20	73	.0250	52.5	.0365

per cent, and the fact that the mean results only differed about 6 per cent from the calculations, shows how carefully this factor was determined.

DISTRIBUTION.

The illumination of an object depends on two factors: first the amount of light falling on the object and second the amount reflected to the retina of the eye. In order to calculate the amount of light falling on any given object, we must first determine the photometric curve of the illuminant used, with its shade or reflector if such there be. The normal illumination, i. e., the illumination upon the plane at right angles to the rays of light is determined by the laws of inverse squares $I_N = \frac{C.\ P.}{d^2}$ where C. P. is the candle power and d the distance from the source of light to the point in question. If, however, we wish to calculate the light upon a horizontal plane, we must take into account the obliquity of the rays and we then have $I_H = \frac{C.\ P.}{d^2} \cos \phi$ where ϕ is the angle between the perpendicular and the ray of light. The vertical illumination will be given by $I_V = \frac{C.P.}{d^2} \sin \phi$. If h is the height of the source of light above the plane to be illumined, the above expression for the horizontal illumination can be written $I_H = \frac{C.\ P.}{h^2} \cos^3 \phi$ which lends itself more readily to calculations. From the above formula we can obtain the horizontal distribution curve, showing the intensity of illumination in candle feet at different distances from the foot of the perpendicular below the light.

Figure 9 shows such a distribution curve, the method by which it was calculated being as follows:

The candle power curve is first drawn to any convenient scale, the use of a $\frac{1}{100}$ rule being recommended for rapid work. Distances from the foot of the perpendicular and the value of h are laid out as shown, to any convenient scale. If now the point of light is connected to varying distances from the foot of the perpendicular we can obtain all the values of ϕ by one setting of a protractor. We can also obtain all the different values of C. P. at one time with our $\frac{1}{100}$ scale. The values of $\cos^3 \phi$ can be calculated by means of a table of cubes but for convenience the table is given on opposite page for all whole angles, which would be ordinarily used.

The work hardly permits of a greater accuracy than ½ degree and the values for $\cos^3 \phi$ for half degrees can be obtained from the table by interpolation. We can then obtain the values of I_H by means of slide rule. Except in rare cases it is not necessary to carry the table further than a value of I_H equal to 2 per cent of the maximum value.

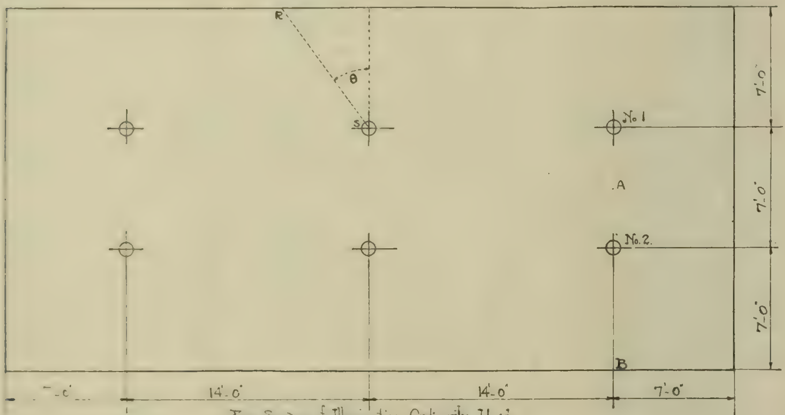
ϕ°	$\cos^3\phi$
1	1.000
2	.998
3	.998
4	.993
5	.988
6	.983
7	.978
8	.971
9	.963
10	.955
11	.945
12	.935
13	.925
14	.913
15	.901
16	.888
17	.874
18	.860
19	.845
20	.829
21	.813
22	.797
23	.780
24	.762
25	.744
26	.726
27	.707
28	.688
29	.668
30	.649
31	.630
32	.610
33	.590
34	.570
35	.550
36	.529
37	.509
38	.489
39	.469
40	.449
41	.429
42	.410
43	.391
44	.372
45	.353
46	.335
47	.317
48	.300
49	282
50	.265
51	.249
52	.233
53	.218
54	.203
55	.189
56	.175
57	.161
58	.149
59	.137
60	.125
61	.114
62	.103
63	.0936
64	.0842
65	.0754
66	.0671
67	.0596
68	.0526
69	.0460
70	.0400
71	.0345
72	.0295
73	.0250
74	.0209
75	.0173
76	.0142
77	.0114
78	.00900
79	.00695
80	.00523
81	.00383
82	.00270
83	.00181
84	.00114

In practice it is found easier to use the table for calculating the illumination rather than the curve, the principal value of the curve being to show graphically the variation of the illumination. It is possible to use the same curve for any value of h; thus if it is desired to use a new height h′ we can obtain the corresponding value of I_H as follows: We have at once $\frac{h}{h'} = \frac{d}{d'}$ whence $d = \frac{h}{h'}d'$. Looking in our table we obtain the value of I_H corresponding to d and this value multiplied by $(\frac{h}{h'})^2$ give the new value $I_{H'}$. This process in practice is very simple and new tables for different values of h can be obtained this way or if desired the same way the original table was calculated.

If the illumination is projected upon the horizontal or some other plane, it is possible to obtain the resultant illumination from a mesh work of lights by adding the separate illuminations arithmetically, and we can therefore obtain the resultant illumination, due allowance being made for the reflection from surrounding objects. In large places where the walls are at considerable distances, this reflection factor can often be neglected.

In street lighting it is customary to use not the horizontal but the normal distribution of light, and although this has its objections, in general it answers the purpose fairly well. For interiors, such as stores, offices, etc., the horizontal distribution is the most important, although with stores, where goods are displayed on shelves, the vertical distribution plays an important part.

In lighting picture galleries and similar places the horizontal distribution is of little value, the vertical being the important consideration. The formula before given for vertical distribution does not hold, however, except for a plane at right angles to the source of light. Thus for example in Figure 10, showing a plan view of a room in which we wish to obtain the vertical distribution, the formula does not hold true for the ray R S, and we must take into account the angle at which the ray strikes the wall. We then have $I_v = \frac{C.\,P.}{h^2} \cos^2 \phi \sin \phi \cos \phi$ where ϕ is the angle between the perpendicular to the wall and the projection of the ray upon the horizontal. In order to use this, we can first consider a table with $\phi = 0$ and then multiply the corresponding value of I_v by different values of $\cos \phi$. In this way it is possible to calculate the illumination falling normally upon the wall from a given mesh work of lights.



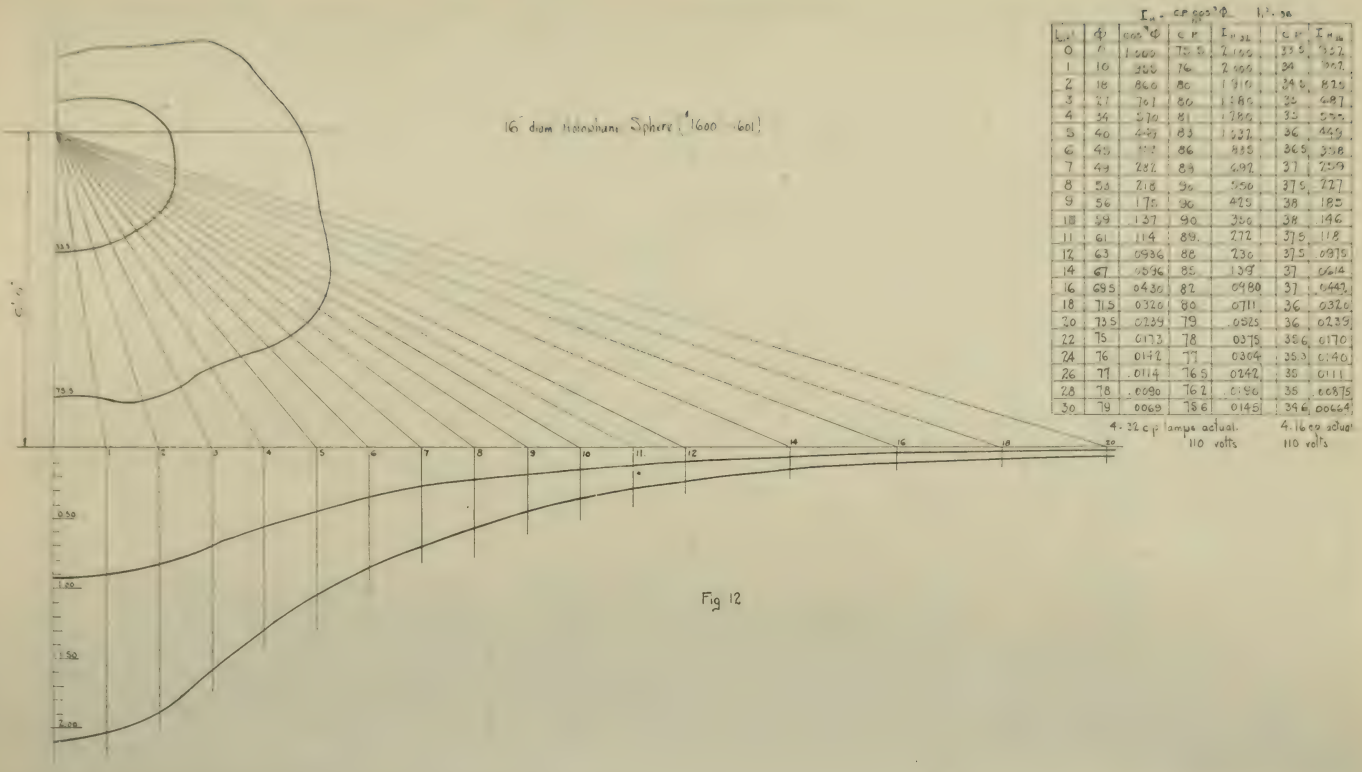
Poor System of Illumination Ordinarily Used

Fig. 10.

Before going further it may be well to note some examples of bad distribution. Given a room shown in Figure 10 it is customary with architects to lay out the lighting as shown. If the lights used had the distribution curve shown in Figure 9 with the height as there given we would obtain a value at the point "A" from the lights 1 and 2 of 2.48 candle feet. At "B" we would obtain a value of 0.602 candle feet. We thus see that there is a great variation in the horizontal illumination at these points. This would be somewhat offset, however, by the reflection from the walls, ceiling and decorations of the room. It must be noted, however, that an even distribution of illumination must often be sacrificed to artistic effect and in the case above considered, it would not be advisable to place the lights nearer than five feet to the walls although four feet would give an illumination at point A of 1.16 C. F. and 1.10 at point C. Illumination is not, therefore, merely an engineering problem, as the artistic and esthetic results must always be borne in mind.

In order to bring out the foregoing principles more clearly we will take for example the lighting of a large office room. The plan and elevations of this room are shown in Figure 11, which shows both the old and new systems of lighting. The former used bare 10 candle power incandescent lights, placed on the beams as shown. The decorations of the room are dark green, the floor of red and white rubber squares and the furniture and woodwork mahogany. It was therefore impossible to allow very much for reflection, especially as a large part of the walls and ceiling was occupied by windows and large skylights shown by dotted lines in the plan, which gave a good light during the day. The effect of all these bare incandescent lamps on the eyes was extremely hard. A person working at one of the desks at the west end would catch the full glare of these lamps from one side of the beam every time he glanced up, and as no desk lights were used, the strain was extremely disagreeable, while at the same time the amount of illumination was not sufficient for comfortable work, the maximum amount falling on a desk being 1.21 candle feet. One of the first things noted about this system was that all the lights on the far side of the beam were practically useless for lighting the desks on the near side, as is shown in the longitudinal section, where it is evident that all such lamps throw no direct illumination at a point 5 feet from the edge of the beam and that, therefore, a large percentage of the light was useless. It should also be noted that roll top desks were used and that consequently a good deal of the light was cut off by the tops, and as the reflection from the walls was small, this light also was practically useless. This is shown by the straight lines drawn from desks No. 1 and No. 2, which show that all the lights on the near side of the beam within the angle enclosed by the two lines are useless, as far as direct illumination on the desk in question is concerned. This applies, however, not only to the old but the new system of lighting. Provided flat top desks were used the increase in illumination would be considerable. A study of the distribution curves actually used show that the summation of all the illumination received from lights beyond a radius of 35 feet is negligible.

It is apparent at once in calculating the useful illumination in a situation like this that it is necessary to use the horizontal rather



$I_H = \frac{cp \cos^3 \Phi}{h^2}$ $h^2 = 36$

L.	Φ	cos³Φ	c p	I H 32		c p	I H 16
0	0	1.000	73.5	2.100		33.5	932
1	10	955	76	2.000		34	902
2	18	860	80	1.910		34.5	825
3	27	707	80	1.580		35	687
4	34	570	81	1.280		35	554
5	40	449	83	1.032		36	449
6	45	354	86	835		36.5	358
7	49	282	89	692		37	289
8	53	218	90	550		37.5	227
9	56	175	90	425		38	185
10	59	.137	90	350		38	.146
11	61	114	89.	272		37.5	118
12	63	0936	88	230		37.5	.0975
14	67	0596	85	139		37	0614
16	69.5	0430	82	0980		37	.0442
18	71.5	0320	80	0711		36	0320
20	73.5	0239	79	.0525		36	0239
22	75	0173	78	0375		35.6	0170
24	76	0142	77	0304		35.3	0140
26	77	.0114	76.5	0242		35	0111
28	78	.0090	76.2	.0190		35	.00875
30	79	0069	75.6	0145		34.6	00664

4-32 c p lamps actual.
110 volts

4-16 cp actual
110 volts

Fig 12

WESTERN SOCIETY OF ENGINEERS.
Vol. VIII. No. 2.—FIG. 11.
Lansingh on Illumination.

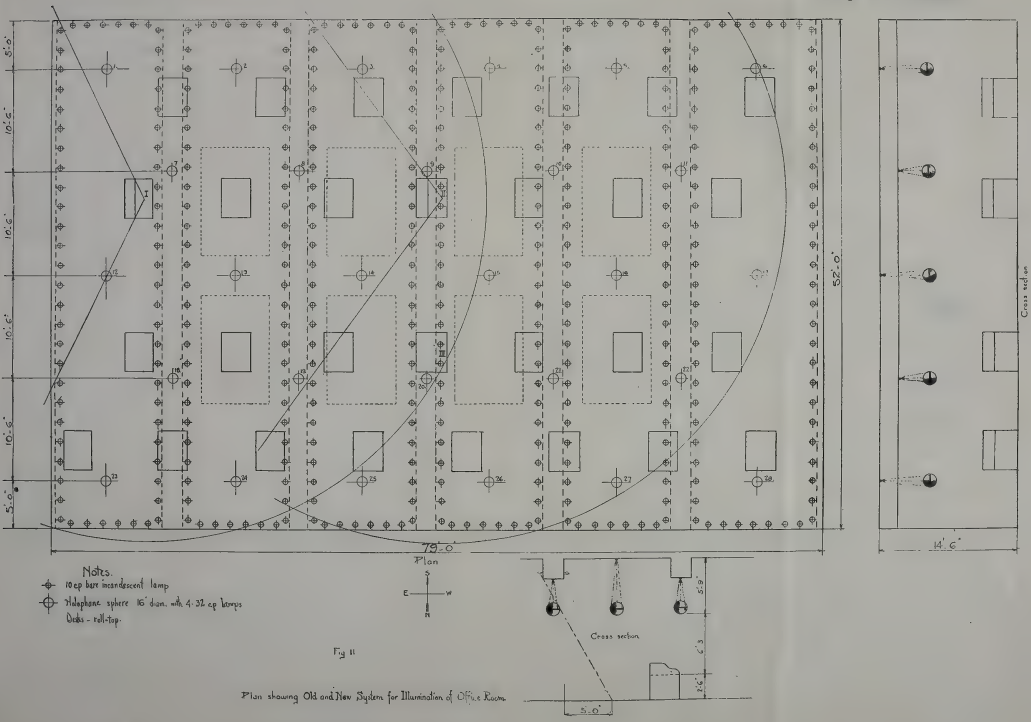
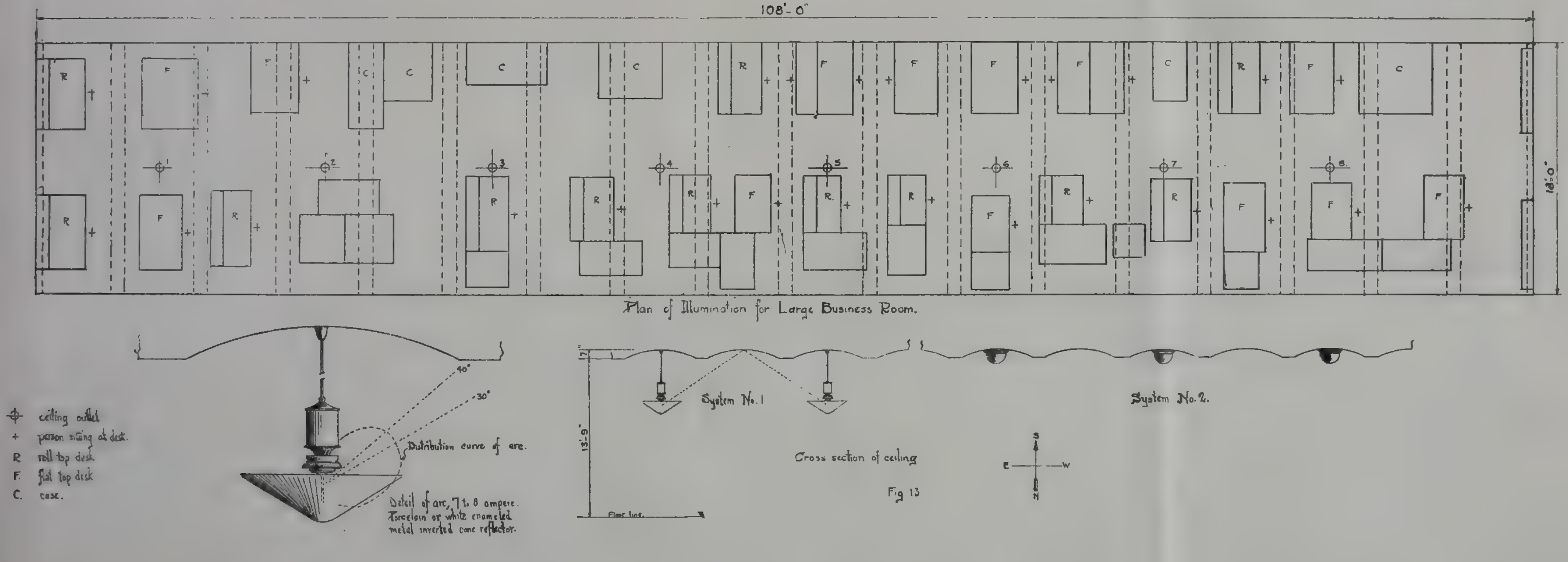


Fig 11

Plan showing Old and New System for Illumination of Office Room.

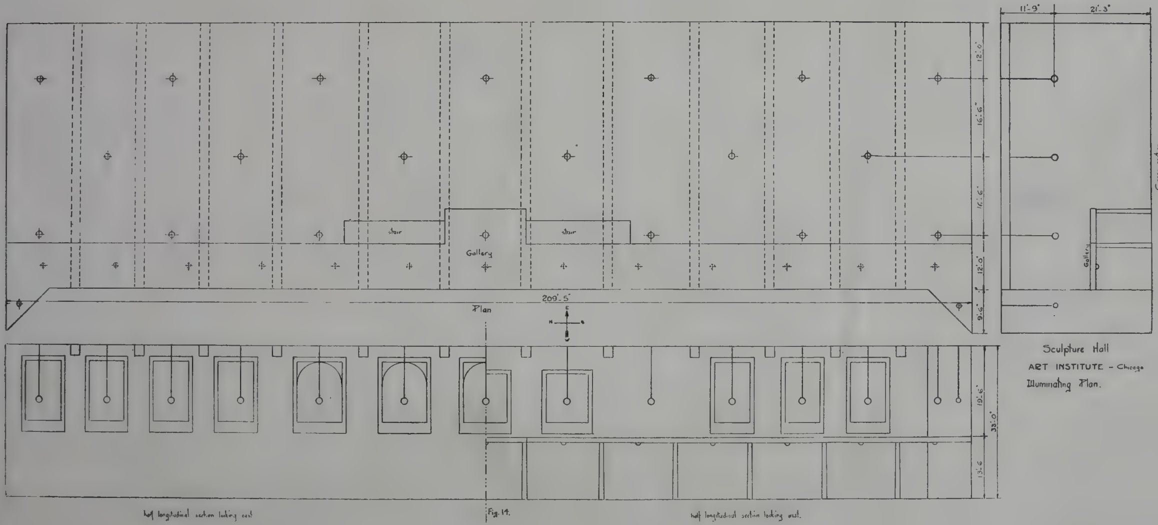
WESTERN SOCIETY OF ENGINEERS.
Vol. VIII. No. 2.—FIG. 13.
Lansingh on Illumination.



Plan of Illumination for Large Business Room.

Fig 13

Western Society of Engineers.
Vol. VIII. No. 2.—Fig. 14.
Lansingh on Illumination.



Sculpture Hall
ART INSTITUTE - Chicago
Illuminating Plan.

than the normal. Figure 12 shows the photometric and horizontal distribution curves actually used. It was decided in this case, after drawing a number of plans to install 16-inch Holophane spheres, enclosing 4-32 candle power lamps. The wires being brought down the chain were practically invisible, and the same could be finished to be in keeping with the decorations of the room. By the use of 4-32 candle power lamps in each of the 28 spheres used, a considerable reduction in the current was obtained. Formerly there were 414-10 candle power lamps, making a total of 4140 candle power, while with the new method there are 3584 candle power, being a saving of 13½ per cent. In addition to this the 32 candle power lamps being of an efficiency slightly higher than 3½ watts per candle, while the 10 candle power lamps being about 4 watts per candle, there resulted an additional saving of at least 14 per cent. The height of these spheres was governed by the artistic conditions.

The illumination obtained on the desks under the old system of lighting was first calculated, taking the sum of the illumination of all lamps and without considering the fact that the person sitting at the desk would cut off a certain amount of light; this gave a resultant lilumination on desk No. 1 of 1.17 candle feet and on desk No. 2 of 1.21 candle feet. The new system was then calculated in the same manner, giving an illumination of 2.60 candle feet on desk No. 1 and 2.98 candle feet on desk No. 2. It is evident, however, that a number of the lights in each case are useless for direct illumination, owing to the fact that a person sitting at a desk will cut off some of the light. This results in more or less shadows, the intensity of which is an extremely important point in desk lighting. The ratio of the effective to the total illumination will give us an idea of the intensity of such shadows and if they exceed 20 per cent they become annoying. Another important point to be considered is the effect of the shadows cast by the hand in writing. For example on desk No. 1 lights 1, 2, 3, 7 and 8 cast shadows if the person is writing with the right hand, while the light on the other side will not cast these shadows. Desk No. 1, however, is one of the worst cases of this kind. If one considers desk No. 3 the intensity of these shadows will be much reduced as the principal illumination is coming from light No. 20. In order to avoid, however, these conditions entirely, it would be necessary to use desk lights, which in the present case was not desired. The location of the lights was governed by two conditions: first, the fact that the paneled ceiling required for the artistic effect that the lights be placed either in the center of each panel or on the beams, and this was still further narrowed by the fact that skylights, shown on the plan, made it practically impossible to place any lights under them. The second condition was the fact that an even distribution of light was wanted over the entire room, as the desks were liable to be shifted at any time. The location of the lights, taking these factors into account, was finally obtained, as shown, although several other different arrangements were tried. The effect of these was not as good as that finally adopted.

One more example of desk lighting may bring out the principles even more clearly. Figure 13 shows the plan of a room used for engineering purposes. The lights as originally installed consisted of eight clusters of 6-32 candle power lamps each under mirrored reflectors dropped about one foot from the ceiling. The effect of these bare lights was extremely trying on the eyes, while, owing to the fact that most of the desks had roll tops on which were cases for books, etc., a large amount of the light was useless, as far as direct illumination was concerned, and the shadows cast were very trying. These conditions, however, were somewhat helped out by the fact that the ceiling and walls were white plaster and a good deal of indirect illumination was obtained. As, however, the north side of the room was almost entirey of factory ribbed glass, and the other side had also a row of glass windows opening on to a hall, this indirect illumination was not sufficient to offset the disadvantages of the system used. It was desired, if possible, to obtain sufficient illumination without the use of desk lights and a number of plans were tried. In every case, however, the calculations showed that owing to the arrangement of the desks, the shadows cast would be strong, which finally brought the problem down to one of two propositions. Figure 13, plan 1, shows a system of indirect illumination by the use of inverted arcs. Most of the light is thrown directly upon the ceiling, while the inverted reflector prevents the light from coming down and throws it back to the ceiling. The candle power curve of such an arc is shown dotted and it will be noticed that the maximum is from 30 to 40 degrees above the horizontal. The height of the arcs was calculated so that the zones of maximum intensity did not overlap on the ceiling. Taking into account the normal distribution this gave a very even light over the ceiling and high side walls. This plan was abandoned, however, owing to its inefficiency. In the first place, the room was located in a large factory where there was a great deal of dirt, the ceiling and walls becoming rapidly coated with dust, which would necessitate frequent cleaning and also whitening the walls several times a year. Even under the best conditions it was improbable that an efficiency of more than 50 per cent could be obtained, while frequent trimming of the lamps owing to the fact that they were inverted, made the cost of maintenance high. Further, as the desks on the south side had to be lighted by artificial light a good part of the day, it would be necessary under this scheme of indirect illumination to burn all the lights all day long, while under the plan with desk lights, finally adopted, only the south lights need be used during the day, resulting in a large saving of current. Plan No. 2 consisted of a good general diffused illumination with use of special desk lights which were intended to cut off the glare directly from the eyes and also to prevent the shadows and streaks as well as the regular reflection resulting from the ordinary reflector. Upon taking these conditions into account it was finally decided to use the present outlets, placing eight 16-inch Holophane hemisperes on the ceiling, enclosing 4-32 candle power lamps, thus removing the glare and giving a good general illumination. As before pointed out the chief objection to the ordinary green reflector is that it casts streaks over the paper, which are extremely trying on the eyes. In order to do away with this, it was decided to use a green porcelain reflector so designed as to admit of a very small Holophane globe within, for the purpose of taking away not only these streaks, but also the glare due to regular reflection which accompanies the use of the ordinary reflector. The same results could have been obtained by using the McFadden or McCreary shades, but at a slight decrease in efficiency, the initial cost of these shades being about the same.

A problem which differs materially from either of the above plans was that of lighting the Sculpture Hall of the Art Institute of Chicago. The plan and elevation of this room are shown in Figure 14. The problem here was not to light the horizontal but rather the vertical, as the room was to be used almost entirely for large sculptural pieces. The height of the lights was governed by the fact that along one side of the room was a balcony, by which people entered, and it was not desirable to lower the lights below the spectator's eyes, as many of the sculptural pieces were considerably higher than the balcony, and the effect of trying to see beyond the lights, as is well known, would be extremely unsatisfactory. The location of the lights was also somewhat governed by the fact that the ceiling was paneled and for artistic reasons it was impossible to place the lights anywhere except in the center of the panels and on the beams. As the walls and ceiling were white and as most of the casts would also be of the same color, it was decided that about 1 candle power per 50 cubic feet would be sufficient illumination. As shown previously, the distribution curve would have to be laid out in accordance with the formula for vertical illumination formerly given. In this way the value of the illumination at different points and at different heights on the walls and on imaginary vertical planes, running parallel and at right angles to the length of the room was obtained and the lights were so placed as to give the best effect, taking into consideration the fact that there would be considerable reflection from the walls and statuary, and that this reflection would be more intense near the sides of the walls than in the center. The original plans of using Holophane spheres was finally postponed and arc lights substituted, on account of the fact that the company supplying the current would furnish the arcs free of cost. It is intended, however, to replace these arcs by the original lighting scheme for which the plans were designed.

A paper of this length does not permit of a further consideration of the distribution question. The general principles laid down here are applicable in most cases. The question of house lighting, however, is not as complex as those considered. In general it is not advisable in such cases to have a uniform illumination. It is better to use a good general illumination and where the light is wanted in some particular place to supplement this by some special light, such as a lamp or candle. The lighting of theaters, churches, and other such buildings presents special problems which must be worked out in detail, always remembering that the artistic must not be sacrificed to the practical.

QUANTITY OF LIGHT.

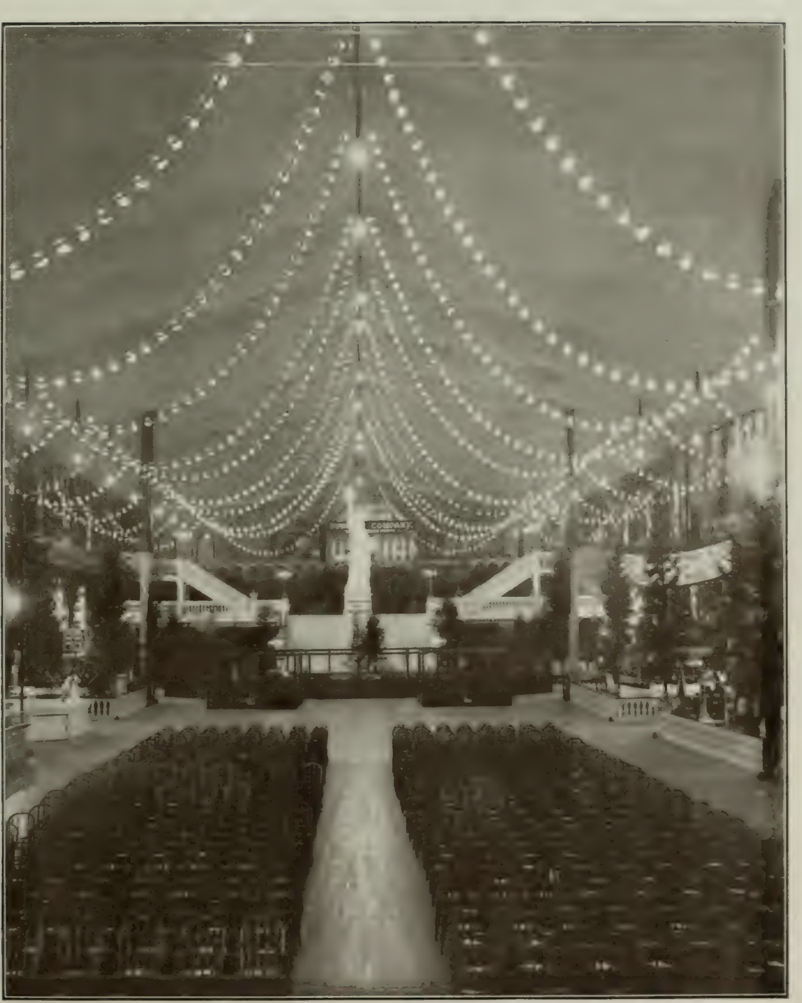
In laying out the lighting for any purpose it is first necessary to determine, at least approximately, the quantity of light to be used. The approximation can later be revised after calculations are made, in case too much or too little light has been used.

The amount of light necessary for good illumination depends upon the purpose for which the place to be lighted is to be used and also on the individual's ideas on the subject. Thus the requirements for street, house and office lighting present great differences. Further the amount of light necessary depends largely upon the character of the surrounding surfaces, such as walls, ceiling, etc., as well as upon the absorption of the shades if such are used as well as their directing power.

There are three methods in general use by which the quantity of light necessary can be approximated:

1st. The number of candle power per square foot.
2nd. The number of candle power per cubic foot.
3rd. The number of candle feet necessary.

The best practice where actual work is concerned is to use all three methods. The amount of light per square foot, as before noted, varies widely, in some cases as high as 1 candle power per square foot, where a very strong light is desired, and again as low as 1 candle power per 5 square feet in a large room where simply a general illumination is required. The mean of these two or about 1 candle power per 3 square feet, when the reflection factor is about 50 per cent is a good working basis for ordinary illumination. For the cubic foot basis the height of the lights from the ceiling



DECORATIVE ILLUMINATION, MILWAUKEE EXPOSITION BUILDING

See page 157

plays an extremely important part. In practice, however, it is safe to allow 1 candle power for from 25 to 50 cubic feet. The latter is sufficient in places where the walls are of light color, but where dark, would not be satisfactory. Under the third method $\frac{5}{10}$ of a horizontal candle foot will give a fair illumination. For reading purposes this should be raised to a minimum of 1 candle foot and for lighting desks, etc., this should be increased to about 2 or $2\frac{1}{2}$ for best results. The writer would like to call attention to some valuable data on this subject, which checks up very closely with his own experience, in Dr. Louis Bell's recent book entitled "The Art of Illumination." *

It is highly desirable to obtain data on this and other kindred subjects relative to illumination, and the writer hopes at a later date to be able to present a table giving the results of a large number of installations, which will include such data as the number of candle power per square foot, candle power per cubic foot, the character of the walls, ceiling, decorations, the nature of the illuminant used, the kind of shades used, the method of distributing the light and other points. If such data as this were collected by engineers, who are engaged in this kind of work, and the same could be tabulated, it would be a most valuable contribution to the literature of the subject.

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* This book has lately been added to the library of the W. S .E.

The frontispiece of this JOURNAL shows a special form of decorative lighting designed by Messrs. Clas and Rau, and used at the Milwaukee exposition. The picture shows about half of the hall with festoons of incandescent lights enclosed in Holophane globes and with red paper shades. There are also some No. 3 Glower "Nernst" lamps used in the center with Holophane globes. The lighting effect was very satisfactory.

CLXVII.

THE THIRD RAIL FOR HIGH SPEED ELECTRIC SERVICE.

By Ernest Gonzenbach, M. W. S. E.

Read March 18, 1903.

During the last year or two numerous interurban electric railways have sprung into existence all over the country and there are still more being planned. Many of these railways are classed as "high speed," a somewhat vague term which it would be difficult to accurately describe. Street cars when they make 10 to 12 miles per hour are decidedly "high speed" cars, and elevated railways with their schedule speed from 13 to 16 miles per hour are a still higher development of high speed service; but for the purpose of this paper we must confine ourselves to strictly interurban railways, having a schedule speed of 20 miles per hour and above. Even among the latter class there are opportunities to question the correctness of the term "high speed." As an example may be mentioned a certain railway which has a run of 18 miles without stops or serious grades and curves. The time consumed for this run is 45 minutes, or a speed of 24 miles per hour. Yet this road must be classed distinctly as a slow speed road, while another road which operates with a schedule speed of 21 miles per hour and numerous stops is one of the best examples of a high speed road in existence. It appears therefore that the term "high speed," as applied to interurban railways, is not determined so much by the maximum speed of the cars in miles per hour as it is by the number of stops these cars make.

These interurban railways at first were built along highways, sometimes in the center, sometimes on one side. Gradually they commenced to be built on their own private right-of-way, always, however, retaining numerous birthmarks of their plebian horse car origin. It is only recently that any marked movement has occurred towards closer identification with steam railway practice. The largest majority of interurbans continue to use the trolley and overhead system of feeders in order to supply power to cars. This is only natural in view of the excellent service the trolley has given for so many years in urban and suburban practice. There are new conditions which present themselves, however, when the trolley is used to supply power to cars or trains drawing from 500 to 1,000 amperes, and at a speed of 40 to 60 miles per hour. The contact area of a single trolley is but very small, while it is amply sufficient for the demands of the ordinary street cars; its behavior under interurban conditions can best be studied by watching one of these cars at night in the open country, and when it is running at its maximum speed. Under such conditions serious arcing occurs at the point of contact of trolley wheel and wire; the color of the flame is a greenish white, indicating burning copper and the size of the arc is proportional to the amount of current taken. There is a gratuitous illumination of the landscape due to this arc, and it gives the advantage(?) of indicating the position of cars at night, somewhat the same as the vertical beam headlights in use on fast steam trains. However, the expense of such an arc is really prohibitive, for it rapidly wears trolley wheel and wires. It should, of course, be understood that it is present at all times, but it is not visible during daylight hours. Trolley wheels are worn out at the rate of one every three to five days; even the best do not last over one week. The trolley wire is rapidly worn and soon breaks at the weak spots. Experience shows that the trolley wire wears most on grades and curves, wherever cars take a large amount of current. Unfortunately, no data is available from which the total maintenance cost per mile of overhead trolley may be obtained for interurban work, and which includes the cost of renewal of trolley wires. That this depreciation is a very high figure, is generally admitted, as is also the fact that maintenance figures obtained in urban work are not applicable for interurban calculations. There is in addition to the high operating cost of trolley wires and wheels, a serious chance for trouble when the trolley leaves the wire at high speed, in which case not only the trolley pole becomes useless, but more often the pipe brackets carrying the wires are ripped off the poles for a considerable distance, and sometimes the car roof is damaged. All these limitations have no bearing when cars are operated at comparatively low speed.

The third rail method of operation is particularly suited to meet these objections and provide a satisfactory and inexpensive current supply for cars running at high speed, although originally it was not designed for such work. Its first use was on the intramural railway at the World's Fair in 1893. From that beginning it soon was adopted for use on the Chicago elevated railways. These roads adopted the third rail with a view of avoiding the unsightliness of overhead wires on an elevated structure rather than on account of any specific advantages in the supply circuit. The first application of the third rail on a surface railroad was on the Nantasket Beach branch of the N. Y., N. H. & H. Ry. In view of the extreme conservativeness of steam railroads on the subject of electric traction, it is interesting to note that we owe the application of the third rail to surface work to one of their number. After the original installation at Nantasket, the same steam road equipped several of its branch lines in Connecticut with this system. The next and the first strictly electric railway to install a third rail surface system was the Albany & Hudson Ry., then follows the Grand Rapids, Grand Haven & Muskegon, and the last and most prominent to go into service is the Aurora, Elgin & Chicago. At present there are a large number of projects planned and building, using the third rail system.

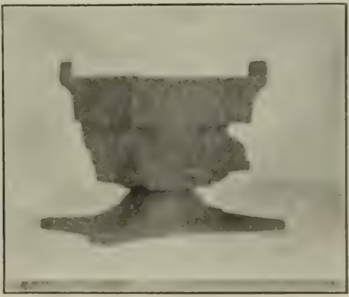
It should not be necessary to mention that the third rail is by no means a *sine qua non* for interurban railways, the trolley is and always will be the most suitable of the two methods for a certain class of railways. If the latter is very largely on streets and highways, or the right-of-way is located adjacent to and parallel with a highway, then the trolley is by all means the most suitable method of conveying power to the car, all the more so because in such cases high speed as we understand it in this case cannot be successfully maintained. Whenever a considerable portion of the roadbed is private right-of-way and not located too closely to the highway, then the third rail becomes advisable from the dollar and cents standpoint as well as from purely engineering causes, and for cars taking considerable amount of current at relatively high speed is really the only satisfactory method.

CONSTRUCTION DETAILS.

The present practice is to locate the third rail at one side of the track, and this practice is to be highly commended on account of the facility with which it enables the ordinary track work to be done, the ability to install the third rail at higher elevation from the ties than if it were placed in the center and the convenience of current collecting mechanism or shoes on the car, which may be located at one side of and suspended from the journal boxes. There is also less liability of short circuits. In fact, this location of the live rail has now become sufficiently standardized, so that words in its favor seem wasted. The distance from gauge line of track rail to center line of third rail is usually about 20 inches in elevated practice and about 27 inches in surface work. The elevated standard is one much to be commended for surface work, for in addition to the ability to interchange cars with the elevated, it gives an extreme width over the third rail shoes which is no more than the width of the car itself, and thus avoids lifting mechanisms and similar devices intended to protect the shoe when car is in city streets and using the trolley. The distance from top of track rail to top of third rail is now generally about six inches, which is a convenient height for allowing ample space for insulators under the third rail.

The location of the third rail at one side of the track necessitates ties for supporting this rail which must necessarily be longer than the standard track tie. In elevated service insulators are usually placed five to six feet apart, while in surface work a distance of ten feet between insulators has become standard, and with the size of rail in use and the absence of vibration present in the elevated structure, this standard is liable to remain. For insulators spaced ten feet apart, and a standard tie spacing of two feet between centers, every fifth tie must have an extra length, or be approximately nine feet long, in order to accommodate the insulator. On roads using all hardwood ties, these extra long ties may be of the same material as the balance, but when cedar ties are used it is usually considered better practice to make the third rail tie of some hardwood, like oak or chestnut.

In order to insulate the live rail, the early third rail systems all used wooden blocks and their use is continued on some roads now building. For elevated service these blocks will serve fairly well, especially when they have been dipped in some insulating compounds. There is perfect drainage of the structure, and water cannot possibly accumulate on elevated tracks. It is nevertheless noticeable that the most recent installations of elevated railways, the Boston and New York roads, have not used wood at all. The insulators on the N. Y., N. H. & H. Ry. were also of wood and its use on later surface roads was no doubt copied from the former. Briefly, the objections to wood are that it absorbs water and allows a heavy leakage which many times destroys the insulator. When new, and in dry weather, it forms a very excellent insulator, but a surface roadbed cannot have the perfect drainage of an elevated structure, and the water will accumulate and be absorbed. As an example may be mentioned the Albany & Hudson Railway. Its third rail is supported and insulated by wooden blocks dipped in insulating compound, and fastened to ties by lag screws. For several months after its installation, the insulation resistance of the third



Wooden Insulation for Third Rail Burnt by Leaking Current rail was very high and the situation looked very favorable. Trouble with the wooden insulators did not appear until the following spring, when snow which had been packed around the insulators and rail for several weeks without the least interference to service, began to gradually melt and this caused ties and insulators to become completely permeated with moisture and introduced a serious leakage. In several instances insulators were found burning, and a peculiar characteristic of that was that they were almost invariably burned in the center, while the outside remained intact, thus indicating clearly that the water had been absorbed by capillary attraction from the tie. It was impossible to determine the total leakage current, because at the same time there was a great deal of trouble from crossing cables, and the two sources of leakage could not readily be determined separately. After the spring thaws were over and sun and leakage current together had dried out insulators, the resistance again became higher. Readings then taken at various points along the line, and so arranged that the cables were not included, showed a very large variation between the various sections, and the same section, with no change in weather, would hardly give two readings alike from one day to another. The writer has no recollection of any insulation reading exceeding 12,000 ohms per mile, the average seemed to be between 6,000 and 7,000 ohms and sometimes it would go as low as 2,000 ohms under ordinary weather conditions. It was found that a single charred wood insulator would permit a leakage of about 2 amperes, but this value will depend very much on local circumstances. Curiously enough the ties which supported the burning insulators did not themselves appear to have been much damaged. The above observations on the Albany & Hudson road were made almost two years ago, and the writer has no data available on the behavior of the insulators since that time. The wood insulators on the Aurora, Elgin & Chicago Ry. have hardly been in use long enough to permit conclusions to be drawn, but indications are that they will be found to have a very low insulation resistance and in fact quite a number of burned ones have already been found and replaced. It would seem from the above that a higher standard of insulation should be demanded, and there is no reason why the same standard demanded for overhead construction should not be reached in third rail work.

The conductor rail is usually of a standard T rail cross-section, but is rolled from a grade of steel containing a very small amount of carbon and manganese. For a resistance in the conductor rail of 7.5 times that of copper of equal cross-section, the steel companies supply a rail containing about .12 of 1 per cent of carbon, and .14 to .15 of 1 per cent of manganese. The standard mixtures used in rolling service rails for steam and electric railways contain very much higher percentages of both carbon and manganese, and their conductivity is usually about $\frac{1}{12}$ that of copper of equal cross-section. It is therefore apparent that the value of steel rails for use as electrical conductors depends not so much on the price per ton as on the conductivity, and Figure 1 is intended to give a comparison of the value of the various mixtures.

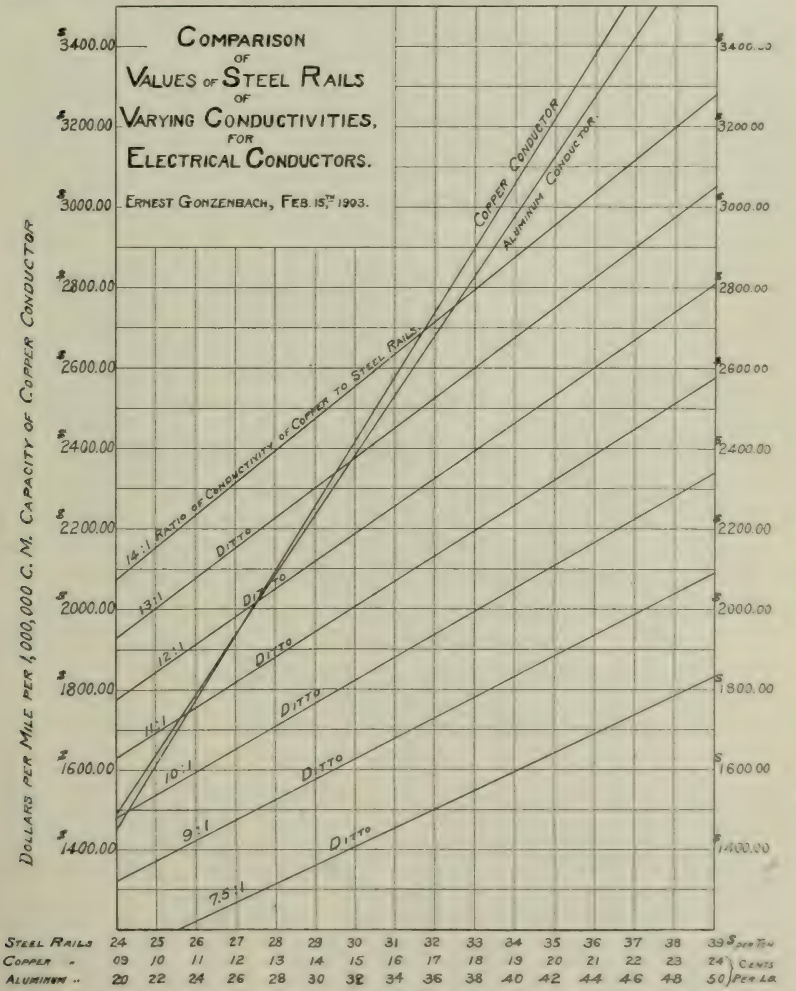
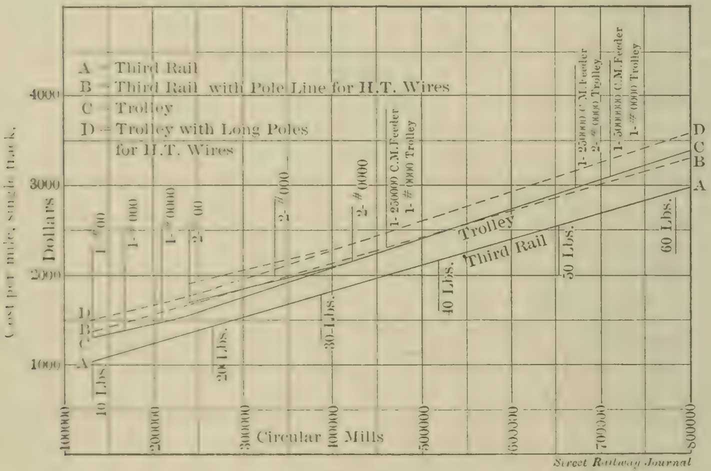


Fig. 1

In some instances old worn out rails have been used for conducting current and Figure 1 was prepared by the writer primarily to determine the commercial value of such rails. As a matter of convenience, the relative cost of copper and aluminum are shown on the same chart, and the horizontal lines represent the cost per mile of conductor equal to copper of 1,000,000 C. M. cross-section. It will be observed that relayer rail with a ratio of 12 to 1 may be sold for $24 per ton, and soft rail having a ratio of 7.5 to 1, bought with the money for $37.50 per ton, and still leave a slight gain in favor of the soft rail. As a general rule it may be stated that old rails sold as relayers will usually net enough cash to buy the low carbon rail of equal conductivity, and leave a cash balance besides.

The ratios shown in Figure 1 should only be used when comparing rails of varying conductivities and not when comparing the cost of steel rails with copper or aluminum, because the values as shown include no bonding or construction work of any kind. When comparing the cost of third rail versus trolley construction it is safer to use the curves prepared by the writer, shown here.



Street Railway Journal

Fig. 2.

These include all construction costs, and in addition the rail conductivity there computed has a very liberal margin to allow for unequal steel mixtures, bonding, cables, etc., all of them factors which are liable to reduce the calculated conductivity.

One of the small details which has proved important on high speed third rail roads is that of joint plates. The early roads and the elevated roads both used a plain strap to connect rail ends. The aligning is comparatively unimportant at low speeds, but at a high speed, however, a slight unevenness will cause the shoe to jump and cause a disagreeable flash, and to avoid this the rail ends must be carefully and rigidly aligned and the "burr" taken off the two adjacent edges with a file. The Manhattan type of joint plate was adopted on the Aurora, Elgin & Chicago Railway and is giving very satisfactory service.

It may be mentioned in passing that all third rails when new cause some sparking at the shoes, and it requires several months of operation to wear down the rail to a smooth surface, giving a good contact without sparking. It is during these first few months, however, when visitors with a critical eye are most numerous, and thus many people have the impression that this sparking is a regular feature of the third rail operation.

In place of the joint rails and bonds, it is possible to use a cast welded joint, which might have advantages for this class of work, but it can not be expected to exceed the convenience and efficiency of the foot bonds hydraulically pressed in place which have become almost universal for this kind of work. The convenience of applying these bonds, the absolutely perfect contact they make when in place and the flexibility they give in handling the rail in case work has to be done or changed after it has gone into service, make them the almost universal choice for this work.

Expansion and contraction of the third rail is not as serious a matter as in the service rail. A joint spacing similar to standard track rail spacing is usually used, but the writer's experience leads him to recommend a close butting of the joints, leaving no space whatever and drawing the joint plate tight, regardless of any chance for movement due to expansion or contraction. The rail may then be rigidly anchored midway between two highway crossings. In this way the extreme movements of the rail end may go as high as 12 to 15 inches, but since it occurs at crossings where the rail is naturally terminated it is of no consequence.

The highway crossings are an important part of the third rail installation. The current must be carried from rail end to rail end with the least expense and a minimum risk of failure. The most ideal way would be to provide standard underground single ducts, and drawn in cables, but this is expensive. The cable used should have the same conductivity as the rail, and in most cases is of about 1,000,000 C. M. size. This is a large and expensive cable costing over one dollar per lineal foot when installed and exceedingly expensive to replace should it fail, especially when the renewal has to come out of the operating costs. Engineers who have had experience in operating underground cables for railway and power supply in large cities realize the difficulties which are met in installations of that sort, although their cables rarely terminate out of doors close to the ground and exposed to water and mechanical shocks. All of the latter conditions have to be met in third rail crossing cables, and in addition the latter must be capable of withstanding the excessive overloads liable to occur in railway work and should therefore have a paper insulation in preference to rubber, to prevent overheating and melting the rubber.

If one is satisfied with low insulation, it is very easy to purchase ordinary triple braid weather-proof cable and install it buried in a trough filled with pitch and tar. This method is cheap but its durability and insulating quality is as yet uncertain. Paper cables, lead covered, would seem to be most advisable and if properly installed should not give much trouble, although it is well to bestow on these cables the same care and attention which the large operating companies give their underground feeders. Periodical insulation readings carefully recorded should be made and as soon as any cable gives signs of weak insulation the cause must be ascertained and remedied. The terminals of each cable must be arranged so that there is no possibility of any current leaking to the lead sheath even in the wettest weather. In order to further guard against this possibility a small copper wire should be *soldered* by a lug to the lead sheath and the other end of the wire connected to one of the track rails. It is also of the greatest importance to be able to disconnect conveniently and rapidly each cable from the rail for the purpose of testing and reading cable and rail insulation, locating short circuits, etc. In order to prevent the contraction and expansion of the rail from doing mechanical injury to the cable, it is good practice to make the connection between the two by three or four extra flexible pieces of cable about 20 inches long, one end of them bonded to rail, the other end sweated into a convenient lug which is attached to the cable terminal by a screw.

When cars pass over highway crossings which have a distance from rail end to rail end longer than the distance between third rail shoes the car lights will be momentarily extinguished, and this has been the cause of much annoyance to passengers. To remedy this fault seems to be a problem which comes under the heading of car equipments rather than third rail, and will not therefore be discussed here.

The third rail shoes carried by the car are within the scope of this paper, however, and may be briefly referred to. The shoes weigh from 14 to 18 pounds each and are supported by two cast links which allow some freedom of movement to the shoes. There is no force holding the shoe on rail except its own gravity. The shoes are usually supplied with a perfectly flat and chilled wearing surface. When making renewals of shoes it has been the practice of the writer to have this surface cast concaved with a radius of 12 inches, which is the radius given to the top of steel rails. In this way a very much larger contact area is secured and sparking is reduced to a minimum from the start. Instead of a cast iron shoe with chilled surface a mild steel shoe has been found very much superior. The life of shoes is as yet uncertain, and there are no records in existence, to the knowledge of the writer, which give accurately an extended record of the mileage of third rail shoes. General observation by the writer leads him to believe that the average life of a shoe lies somewhere between 15,000 and 25,000 car miles, and as the cost per shoe and pair of links is about $1.35, this cost of renewal is exceedingly low and not to be compared with trolley wheel renewals. At present all roads are equipped with third rail shoes which depend on gravity for contact with the rail, though the Boston Elevated supplements this by a long coil single turn spring giving about 15 pounds additional pressure, and the officials of that road are very well satisfied with this arrangement. Lately, Mr. W. B. Potter, of the General Electric Company has designed a shoe which is worked by springs and which will at once appeal to practical men. As put on the market it is designed to extend out horizontally and make contact with rail under a covering, also designed by Mr. Potter. Whatever the merits of this protected third rail may be, it is certain that the shoe designed for it, or a modification of it, would meet all the objectionable features of the present form of gravity shoe.

The merit of a covering for the third rail seems to be open to question. The covered third rail as designed by Mr. Potter should avoid difficulty from sleet, but it remains to be proven if such a covering would be suitable in open cross country work where snow is liable to drift and be packed tightly between the rail and the covering. It might prove more difficult to dislodge the snow from such a location than it is to get rid of sleet. Coverings or protection of any kind have not been found to be necessary as a preventive of accidents. It may occasionally be advisable to protect the rail to some extent when near houses, in yards, etc., and for this purpose the writer recommends a close fitting sheath of wood, leaving the top of the rail exposed. Sleet is probably the most serious of all objections to third rail operation and it is well known that in the early days and on many new roads, operations have been suspended for hours while sleet clung to the conductor rail. Sleet cutting devices in innumerable forms have been tried; few of them have been very successful. The steel scrapers in use on most of the Chicago Elevated roads seem to be the most successful so far. The New York Elevated uses steel brushes worked by air pressure, while the Boston Elevated has been remarkably successful in the use of a steel brush held against the rail by a spring giving a total pressure of about 35 pounds. This is just the amount of pressure required to press the particular style of brush used against the rail without bending the individual wires composing the brush from a vertical position. The Albany & Hudson tried innumerable devices and the most successful seem to be a modification of the Chicago scraper held against the rail with a very heavy pressure. The Aurora, Elgin & Chicago has been using salt with success, supplemented by steel brushes. The writer confidently believes that the use of brine judiciously distributed just ahead of a steel brush of the Boston Elevated type will eventually be found to be most useful, and that in a very short time we will have learned to meet the sleet problem and have permanently disposed of it.

Choosing the size of the third rail for an interurban high speed railway, corresponds to designing the distributing system of an ordinary electric railway. When there are auxiliary feeders of either copper or steel the size of the working conductor is comparatively unimportant, but when it forms the sole feeder as it does on most surface systems, then it must be carefully chosen. As a rule high speed railways of the kind we are using for examples are too long to make a direct current station advisable and they are therefore designed to generate alternating current delivered to rails through rotary converter stations. The number and location of these sub-stations will affect the size of the third rail, and there seems at present to be a tendency to use fewer sub-stations and heavier rail. In the writer's opinion this practice is erroneous, although when sub-station attendance is high, it may *apparently* be the least expensive. Unfortunately, a practice has grown up of making sub-stations little miniature power-stations and providing in them all sorts of engineering freaks in the way of apparatus. Such a station requires skilled attendants, and even when there are only two shifts, the wages form the largest item of sub-station expense. Again, sub-stations are often located by the manufacturer of the electrical apparatus, who places them so as to get the most ideal power distribution, and quite regardless of any other useful purpose they might conveniently serve. Sub-station location is a subject beyond the scope of this paper, but it may be remarked in passing that if sub-stations were located more numerously and judiciously and more simply designed, they might serve a most useful purpose as passenger, express and freight depots, as distributing centers for power and lighting supply and other by-products of an electrical plant, and their attendance would become a small part of the expense chargeable to motive power. In fact, there seem to be no reason why they should not become sources of income instead of being a dead weight on operating expenses. With attendance eliminated, the size of rail can be very closely determined by comparing the interest and depreciation of the third rail and track circuit with that of the sub-stations. If the track rails are a fixed size, then the size of the third rail to be chosen will be found when its interest and depreciation very closely equals the sub-stations.

Practically, however, the sub-stations should be located as near the heart of towns and villages as possible, and third rail determined afterward.

The third rail and a judicious arrangement of the alternating current feeder system will serve as the most convenient power supply for long high speed railways for many years to come, and the strictly single or multiphase railway using high tension current on the car will have difficulty to show advantages over a properly designed and operated third rail direct current railway system.

DISCUSSION.

Mr. Geo. E. Thomas, M. W. S. E., New York (by letter)—In regard to a third rail being first used on the intramural railway at the World's Fair in Chicago in 1893, I beg to differ from the author of the paper, as I used a third rail, or its equivalent, on an electric railway in Dupont Park, Louisville, Ky., at the Southern Exposition in 1883. This was a flat bar 3½ x ⅝-inch set on edge in chairs fastened to the ties and about midway between the wheel rails. Electric connection to the motor on the car was obtained by a metal brush which spanned this bar. The motor, etc., was the production of Thomas Edison and Judge Field.

Mr. Paul Winsor, Boston Elevated Railway (by letter)—I have read the paper very carefully, and the only points I see are two which I do not think are thoroughly covered. These are:

FIRST: As Mr. F. H. Shepard, formerly with the Sprague Electric Co., has persistently stated, the necessity of "isolation rather than insulation."

SECOND: The advantages of, where possible, sectionalizing the third rail and using it as a trolley rather than a feeder.

In our experience with the Boston Elevated we have found that the third rail insulators should be made entirely of insulating material, so that the greatest possible insulating distance can be obtained between the live rails and the ground. On elevated work this is particularly necessary owing to the close proximity of the structure to the base of the insulator, the insulators often coming at points where there are hook bolts fastening ties to the steel work, iron plates under rails, etc., etc. The first insulators we used were made mechanically very strong, consisting of a malleable iron base with a malleable iron petticoated top, the two separated from one another by one of the best known forms of overhead insulation. These insulators were excellent when first put in, but the material would not stand the continual jarring under considerable pressure and many broke down by the cracking of the insulation at the point where the material was joined in the mold. The base of this insulator was lagged to the ties with three lag bolts, and we found them extremely difficult to remove after having been in service for some months. In one case, where the insulator failed, it took us nineteen minutes to get the insulator out after the current was shut off, although close to headquarters and men and tools available. The insulators were so strong that it was impossible to break them with a sledge, and were so surrounded with guard timbers, etc., that it was extremely difficult to back out the lag bolts. We found the petticoats of very questionable use. The dust and dirt, especially brake shoe and rail dust at points where brakes were used, as approaching stations, coated the insulator with rust which was impossible to remove, and the rain striking on the ties would spatter up under the petticoat so that it was practically full of a cake of rust and dirt.

We have designed, and are putting in use, a form of insulator which will be made of terra-cotta or re-constructed granite, which consists of a cylinder of this material resting on a flat face plate and with a flat top, both of malleable iron, and both cast with tubular projections which are cemented into the terra-cotta or re-constructed granite. This gives a straight, smooth insulating surface between the cap and base of 5¾ inches, which, in connection with the wood ties, should give us the necessary isolation. We have not used these insulators long enough to see how they will work in practice.

I believe salt to be a very dangerous experiment, although perhaps necessary to remove sleet on cross-country lines having comparatively infrequent service. It will penetrate the wood ties and coat the surface of the insulators to such an extent as to often cause serious leaks and insulator burnouts.

I believe, if possible, the third rail should be cut into sections and used only as a trolley. This makes it possible to kill a section of the third rail without shutting down the road, making it much easier for the track men on their track work and much easier for the men when third rail work is to be done. In cases of derailment, or the like, the current can be quickly cut off and the blockade much more quickly cleared. This is especially important in cases of lines of very dense traffic, as on elevated work.

Mr. Gonzenbach.—In reply to Mr. Thomas' criticism regarding the first use of the third rail:

There is no question but that the third rail was used prior to the trolley. In fact, I think some of the very earliest experiments with electric traction used some sort of metallic conductor near to the ground and not elevated or very high in the air, which in some forms might be termed a third rail.

I have also heard of some earlier experiments carried on by the

New York Elevated Ry. Co.—the 34th street branch- in which they used the third rail but which was abandoned before electric traction was very far developed.

I will simply state that as far as I know the third rail was for the first time commercially used at the World's Fair on the intramural railway.

In regard to Mr. Winsor's discussion, I want to say that I agree with him fully as to sectionalizing the third rail where possible, using it as a trolley rather than a feeder. That thing is possible on a road like the Boston Elevated, or a road consisting of a network of tracks, but for a strictly high speed cross-country road consisting of a single track and a straight run from end to end, such a thing is out of the question because the third rail must be the conductor of the current and there is usually no other conductor provided, consequently sectionalizing is commercially inadvisable.

Regarding the insulators which Mr. Winsor speaks of, I cannot say very much on that score because I am a patentee of a third rail insulator myself, but I think that Mr. Winsor overlooks the fact that the material which he puts into his insulators is very brittle and liable to break and does not prevent surface leakage if coated by dirt or moisture. I also believe there is a type of third rail insulator which can be used, allowing salt to be used on the rail with perfect safety.

Mr. L. E. Gould—Having been associated with Mr. Gonzenbach for a couple of years, on third rail work under his direction, it would not be my place to make any criticisms on his remarks; however I would like to say a few things regarding his insulator:

It contains no wood at all, and is made of three separate pieces, which I will describe—a metal cap of malleable iron on which the rail sets and rides freely, there being no clamps of any sort; under this cap is a petticoat much the shape of an inverted saucer, with a hole in its center; this petticoat is made of an insulating compound such as that used in Globe insulators; the cap and petticoat in turn rest upon a standard having the form of a cylinder with a flaring base and notches for being either lagged or spiked to the third rail tie — the spikes, perhaps, costing a little more than lags but being much more rigid. This insulator allows a free movement of the rail lengthwise of the track, the friction of this movement being lessened by two raised sections on the cap casting, which allow a very small area of contact between the insulator and base of the rail, so that when the rails are fish-plated they may be butted very closely together and the expansion taken care of at the road crossings.

On the Albany & Hudson Ry. we noticed a great difference in the expansion of the rails on double track and single track. On the single track the rails were marked and the points watched. (The same thing was done on the Aurora, Elgin & Chicago Ry.) Permanent points were referenced by nails driven in track ties and by prick punch marks on the rail; the longitudinal difference of such points being noted. On the single track the cars passing in alternate directions seemed to do away with any creeping, even on 2 per cent grade where the rails were continuous for about 3,000 feet, but on double track the rail had a tendency to creep in the direction of a moving car, due, I suppose, to the shoes aiding the expansion and contraction of the rail. This would seem to show that rails on double track should be anchored perhaps in the center or at two points a certain distance from either end of a free section, but on single track no anchor would, to me, seem necessary.

I want to make one little statement regarding underground cables.

Mr. Gonzenbach speaks of soldering one end of a small copper wire to the lead sheath of the paper insulated cable and connecting the other end of the wire with one of the track rails. The Albany & Hudson Ry. had a great number of cables burned on account of a faulty make-shift terminal, so someone tried the scheme of connecting the lead sheath to the track rail by a small copper wire, but neglected to solder the wire to the lead sheath. Thus an elecrolytic action was set up and a weak spot formed in the cable sheath. I doubt the advisability of grounding the lead but in event of such being done a perfect connection must be made.

Mr. Tratman—I live out on the Aurora, Elgin & Chicago Ry. and that third rail furnishes us with a very fine electrical display every evening. You can tell where a car is five or six miles away, and the whole sky is lighted up. One important feature of this railway is the rapid acceleration of the cars. I ride on the Chicago & Northwestern Ry. and the electric railway runs alongside the Northwestern tracks for considerable distances. At stations, when an electric car and a steam train happen to start off at the same time, the electric car will easily run away from the steam train, the acceleration is so rapid on the electric cars. On one part of the line there is a plank protection against the side of the third rail. It is just a plank set on edge, and I would like to ask what is the purpose of that.

Mr. Gonzenbach That was done largely to satisfy the prejudice of some of the steam railroad officials when rail was put down on their land. It is not of any practical service.

In regard to the flashing from the rails of the Aurora, Elgin & Chicago Ry., that is apparently a little consideration which the railway people are showing to the people along the line by providing this electric illumination free.

Seriously, however, I think the flashing is due to some extent to the fact that the track men had not been thoroughly posted on the way to handle the third rail. This occurred after the track men have shimmed up the track rail when the ballast was frozen and hard, and the result was that the third rail was, in a good many cases, slightly below where the shoe could reach it and it would draw a tremendous arc when the car passed. When the ground is thawed out it will be remedied to some extent no doubt. However, it is not the intention to discuss here the Aurora, Elgin & Chicago Ry. exclusively, but it is the handiest and most convenient and best known to members of this society. It is not "the only pebble on the beach" by any means, nor the only third-rail road in the country. For instance, the Chicago elevated roads operate the third rail system with very little sparking. In fact I think one can watch the Chicago elevated roads and see very little flashing at any time and I also think it can be avoided by more perfect design of third rail shoe and its suspension somewhat similar to the shoe designed by Mr. Potter. A little more care used in keeping the rail in alignment would also reduce this flashing.

Mr. Tratman—I would like to ask whether on the new line which the Albany & Hudson Ry. have bought, running north, is it the third rail or trolley?

Mr. Gonzenbach—I think that you have two roads mixed. The Hudson Valley is a separate and distinct road. The Albany & Hudson road is the outcome of the old Kinderhook & Hudson road, which used to be a steam road and which was bought by the Albany & Hudson, and the whole was made a third-rail system. Just at present, however, the Albany & Hudson road is in receiver's hands.

Mr. Finley—I would like to ask if the placing of this third rail does not enhance the cost of maintenance of the track work on the road?

After listening to Mr. Gould's description of the insulator and and Mr. Gonzenbach's reference to brine as being a most useful means for the removal of sleet, I would like to ask if it does not cause rapid corrosion of the connections?

Mr. Gonzenbach—The cost of maintenance of the third rail is practically nothing.

Mr. Finley—Do they not have to exercise more care?

Mr. Gonzenbach—I think you will find that the section gangs on third rail construction work as rapidly as when no third rail is required. On both roads that I have been connected with we had to turn on current before all the track work had been finished.

We had gangs of Italians, Greeks, etc. who didn't know much about electricity, and the first day or two they would lay their crowbars across the rails, and on attempting to sit down on the rail would sometimes get up very quickly, but after a couple of days they would become accustomed to the rail and work over and around it, handling the work rapidly and regardless of the rail.

In regard to brine causing rapid corrosion of the connections, it does not get any part of the insulating part of the insulator. The top part of the insulator forms a roof, which drains all water, brine, etc. from the insulator, so that any brine which might be spilled over the rail would simply be thrown off without touching any of the fastenings.

Mr. Finley—I would like a little further information about sectionalizing the third rail.

Mr. Gonzenbach—Mr. Winsor refers to cutting the third rail into sections and supplying an independent copper or rail feeder to each section from the power house, which would necessitate a separate copper or other wire from the power house for each section.

Mr. Charles R. Sturdevant—In respect to the third rail insulator, and with all regard to Mr. Gonzenbach's insulator, I am personally of the opinion that this problem has not yet been successfully solved. The insulator should be cheap and durable, mechanically strong, and it must have good insulating qualities. It is a difficult matter to get any one substance which possesses good insulating properties and mechanical strength. The greatest strain on an insulator is in the direction of the rail. Most insulators, however, have narrow bases and as the rail creeps along will either tip over or will give way in some portion.

While inspecting some of the roads about here recently I have noticed a very neat form of insulator on one of the elevated lines which embodies many of these points; it is cheap and durable, the insulating qualities are high, and above all, it is very strong mechanically. It consists of a long wooden block spanning two ties, and having a specially prepared insulator under each end of the block. The rail is supported by a small casting in the center of the block. It would be better, however, if the insulating parts came directly in contact with the rail.

There is another point which has not been mentioned this evening, regarding the rusting of the metallic parts of an insulator. There is a slight leakage of current from the rails which causes electrolytic action and accelerates the rusting of the iron parts so that those parts have to be made a little heavier on that account.

Mr. Gonzenbach—It is significant that cheapness is the first qualification mentioned for a successful insulator, and it is strange that the word "cheap" should be the main specification for a third rail insulator. On this basis we shall never succeed in getting satisfactory insulation.

Mr. Modjeski—What would be the effect of welding the rails instead of bonding them with side plates?

Mr. Gonzenbach—The effect would be that we would have a very long length of rail, and it is sometimes advisable, in operation, to remove a section of rail from some particular piece of construction account of a slight accident, bridge construction, or anything of that sort. In that case it would have to be sawed, making it rather difficult to remove and weld again, while the ordinary bonded rail is readily cut loose and put on again.

I might refer to Mr. Tratman's remark about the acceleration of the cars of the Aurora, Elgin & Chicago Ry. It is a subject which I would like to hear mentioned more in detail tonight. It is a feature of the third rail roads and surface roads which have been built lately that their cars are invariably designed to have a very rapid acceleration, and it has become rather a by-word that a third rail road is equipped with a very large rail, heavy motors, has high speed and high acceleration. The two do not necessarily go together, but so far, in all surface roads, they have.

In the A., E. & C. Ry., the acceleration of, say, about two miles per hour per second would enable a car to reasonably start from rest and reach a maximum speed of sixty miles an hour in about thirty seconds. It can be approximated very closely. I have personally seen a car start from rest and reach a speed of about sixty miles an hour in about thirty-five seconds. The amount of current drawn for that work is, of course, tremendous. Under other circumstances it might be less. It seems to be a very much debatable question whether such high acceleration is advisable for surface work of this sort. It is certainly very far above what has been attempted in steam roads in the way of acceleration.

Mr. C. Lewis—With regard to this matter of acceleration; as I understand it, the great object of acceleration is to save a little time between stops. This increased acceleration involves the use of additional power, the cost of which can be approximated from the cost of power as produced at the power house. Has any ratio been worked out from such data which would give the cost of the additional power per unit of time saved? The acceleration being effective only on a part of the run, its final commercial value would, I suppose, bear some proportion to the distance between stations.

Mr. Gonzenbach—I believe such a relation could be worked out. It would depend very largely on how much value is placed on the time saved. I have a recollection of a rough calculation which I at one time made; I arbitrarily assigned a certain value to the time and in that case the value of the current and the investment in apparatus required to produce a high acceleration very far exceeded the value of the time saved.

Mr. Sturdevant—My understanding of the question is that the greatest economy of energy per ton mile of train is obtained by a very rapid acceleration up to a maximum speed, then running or drifting at this speed for a short distance and then rapidly brakeing to stop. This saving of energy will, however, be accomplished at the expense of very heavy motor and station equipments, and heavy fixed charges. The starting current will be very heavy, while the average current is small. The total station load will be small, and with few cars it will fluctuate between wide limits, and the load factor will be small. All of the machinery will be running at a low efficiency.

Mr. Finley—The use of brine has proved to be very destructive on steam roads. Here in Chicago I have had occasion to make some investigations and have found that the use of brine has been very destructive on the bridges. I was interested to know whether they would not find the same difficulty with the third rail and was rather surprised to learn that they have not. It is a very vital question.

Mr. Gonzenbach—I think perhaps you overestimated the amount of brine that is required to place on the rails. The brine which is used is not a very strong solution and it is run on top of the rail through a rubber hose of exceedingly small size; it is only occasionally that drops of it will find their way to any extent to the ties.

Mr. Finley—I can hardly appreciate such a small amount of brine giving such quick action.

Mr. Gonzenbach—If you put a drop of brine on some sleet on the sidewalk you will note how quickly it will melt it. The same will hold true in the third rail.

Brine is not extensively used to clean rails so far. The objections which have been urged against it have prevented a good many people from using it. I believe it can be used without detriment but I admit that my position is yet to be proven.

As to the present methods for cutting sleet the names are almost legion; almost everything has been tried. The steel scraper seems to have been most successful outside of chemical means, while again some of the eastern roads use steel brushes, with very thick heavy wire—flat wire—this is pressed, with comparatively light pressure, against the rail, and the Boston Elevated people told me that they had taken a three-car train, with six brushes on one side, over a siding which had not been in use for twenty-four hours, coated at least 1/8-inch thick with sleet, and their style of brush enabled them to go on that siding and use current without very heavy flashing or interference.

Mr. Sturdevant—I am especially interested in bonds and would like to say just a word about them.

I will say that I have come here specially to inspect electric roads, and on one particular road visited I noticed a large number of the joints which had been condemned. The road has been bonded about two years and is being tested by engineers who know their work. There are red marks placed on every fifth or sixth joint. The trouble was undoubtedly caused by the manner in which the bonds were placed.

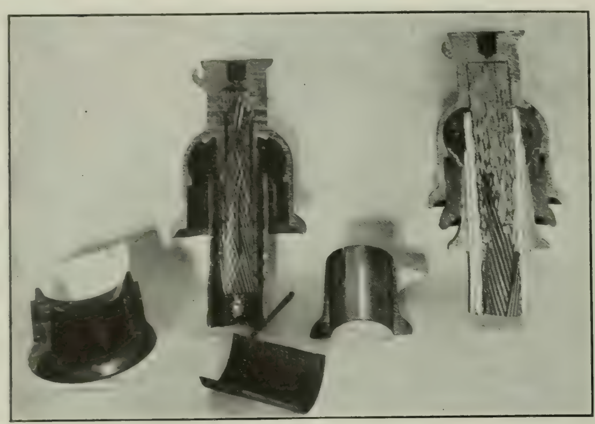
If you employ an ordinary laborer to place the bonds he can do more damage in five minutes than it would receive in five years of service. The bonds referred to were installed in wet weather. I do not know whether they were cleaned and brightened or not, but when they were taken out you could scrape off thick scales of rust. That is the kind of work that results from putting in bonds the wrong way. A bond to be properly installed should be absolutely clean and dry. Both surfaces, the iron and the copper, should be clean and polished, have them dry and then compress the terminals as hard as you can. Then you will have a job that will last as long as the body of the bond on an ordinary road of surface track. Much depends upon the form of the compressor rams, and the manner in which the compressor is applied to the bond terminals.

Mr. W. G. Carlton—In regard to protecting the ends of the paper of the lead underground cable—where cable is exposed to moisture, if there is not a thorough protection I have always found it very hard to keep the moisture out of the paper, and I would like to ask Mr. Gonzenbach if he has had much trouble with those terminals.

Mr. Gonzenbach—I will say that on the Albany & Hudson Ry. they had a form of cable terminal which consisted of a porcelain insulator without the petticoat, and which in wet weather allowed a surface leakage. They used paper cable on that road and we found that we had a combination of circumstances which would enable a very slight leak between a cable terminal, brass cap and the lead sheath of the cable. In some cases in measuring the resistance by the method we would find a leak of perhaps only one or two volts. That would gradually increase until some part of the lead covering was totally eaten away by the electrolysis. I believe that every single cable on crossings of the Albany & Hudson Ry. had to be renewed, and the last I heard was that they were putting the cables overhead.

On the A., E. & C. Ry., the particular cable terminal shown was designed to overcome these troubles. There are a great many more cables on that road than on the A. & H. I believe we had about 280 cables on the A. & H., whereas we had 500 on the A.,

E. & C. and there are only one or two cases where cable has given trouble, which, in view of the Edison and other companies' experiences, would be considered a thoroughly good record.



Third Rail Terminal for Cable Connection.

CLXVIII.

ELECTRIC RAILWAYS.

H. M. Brinckerhoff, M. W. S. E.

This paper is an abstract from a lecture delivered before the night classes of the Lewis Institute as one of a series of semi-popular talks on engineering subjects.

Chicago has been the pioneer in the third rail work, beginning with the Intramural Railway at the World's Fair, down to the present time. She now has the most complete and best equipped elevated railway system in the world, and one that is being patterned after by the systems in other cities, in some cases with a closeness in detail that is really amusing.

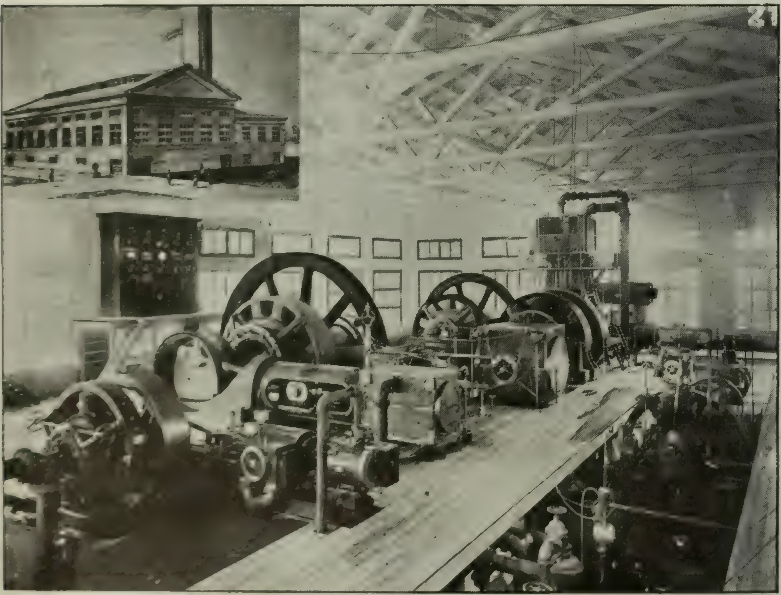
The first commercial third rail system operated in this country was the Intramural railway at the World's Fair, built for the purpose of affording transportation from point to point on the grounds. This railway went into operation almost simultaneously with a third rail system in Liverpool, England, and it was a curious fact that many of the details worked out entirely independently on both sides of the ocean for these systems, were remarkably alike in many of their features.

The Intramural Electric Railway at the World's Fair, 1893.

The Intramural railway consisted of a line of double track extending about the Fair Grounds, three miles in length from end to end, with a loop at either terminal. Trains of four cars were run, each car having a seating capacity of fifty passengers. The head car of the train was equipped with motors, giving what is now known as the locomotive system, as distinguished from the multiple unit system, in which motors are placed in all the cars, the latter being the one used on the South Side railway of this city.

At the time the concession was let by the World's Fair authorities for this elevated railway about the grounds the only known way of supplying electric power to cars, in successful use, was by the overhead trolley. In fact, some of the first sketches submitted to the Fair authorities showed poles and overhead conductors. The use therefore, of a flat shoe sliding on a steel rail was a radical departure, and so general and severe were the criticisms of this scheme, even from men considered authorities on such subjects, that it was with considerable trepidation that the first trial trip was made.

In this feature then, as in many others developed, in designing the equipment of the Intramural railway, there were no precedents to be guided by, and various questions which have since been discussed at length, such as the location of the contact rail, the advisability of equipping the motor car with two or four motors, the best method of sub-dividing the feeder system, the arrangements for the return circuit, and the proportion of the power station capacity to the maximum load to be hauled, had all to be worked out without any reliable data upon which to base the calculation.



Power House of Intramural Electric Railway at World's Fair, 1893.

The fact that this third rail system has been adopted by all the elevated railways in Chicago, Brooklyn, Boston, and finally in New York, as well as on some inter-urban and steam railway lines, naturally leads to these questions:

What are the features of the electric third rail system which have caused its almost universal adoption on elevated railways?

Under what conditions can it be used on inter-urban and steam railway lines?

Briefly, the third rail system is merely a method of supplying trains on an electric railway with current, and differs *only in detail* from all other electric systems where the power is generated in a central plant and distributed by suitable conductors to the cars on the various lines. In starting a 5-car elevated train from 500 to 800 or even 1,200 amperes are required, and if such currents are passed through a trolley wheel, such as is used on street railway cars, very excessive arcing is caused, due to the fact that the wheel touches the wire at only one point. The contact surface is not sufficient to carry this current and burning of the wheel and trolley wire result. With a sliding shoe, however, instead of a single point of contact, you have a surface about six inches long by two inches wide, and two of these in use at once under normal conditions. In other words, the third rail system differs from the ordinary trolley road only in detail. But these details were such as to make possible the application of electric traction to heavier trains than had been found practicable with the overhead trolley.

It thus broadened the field for the application of electricity to railway work, so as to bring it into successful competition with steam for the heaviest classes of service. The reasons for its general *adoption* on elevated roads were on account of the advantages peculiar to *electric traction itself*, viz:

First. Reduction in cost of power for handling trains;

Second. Increase in passenger handling capacity; and

Third. A service more attractive to the public generally.

The reduction in the cost of power is obtained largely from the generation of power in a single central steam plant, instead of a great number of smaller plants, as with the steam locomotive system. On this point of economy, the fuel bill is one of the large items in the operation of a railroad. With steam locomotives, such as were used on the Chicago elevated roads, the only fuel available cost in the neighborhood of $3.50 to $5.50 per ton, whereas, in the modern power house, designed for electric railway systems, coal ranging from $1.25 to $1.75 a ton is burned with entire success. When to this is added the enormous loss in radiation from a large number of steam locomotives, exposed as they are in running over the line of the road and compare this loss with the relatively small one experienced with a well constructed stationary boiler plant, it is not surprising that the cost for coal per car mile on the electric railways in Chicago, is about *one-third* the cost per car mile with steam locomotives. The comparison is particularly favorable here on account of our ability to obtain a very cheap grade of coal directly from the Illinois and Indiana coal-fields. In New York and other eastern cities this difference is not so great, as coal delivered at these points is necessarily higher in price on account of larger freight charges. Besides the saving in the coal bill there is a further gain by the use of large compound condensing engine units. These large steam units having a comparatively steady load, develop power with a very much lower steam consumption than the small engines of a locomotive with their constant starting and stopping and consequent cooling of cylinders, etc. Another item in which a considerable saving is made, is in the cost of repairs and renewals to the motor equipment as compared with locomotives.

The second advantage—"Increase in capacity for handling passengers" is due first, to the fact that with electric motors a much higher rate of acceleration can be obtained in starting trains, thereby increasing the average speed over a given line of road. The trains can also be handled with *so much* greater accuracy and precision that a much shorter interval is perfectly safe; all of these directly contributing to the end of greater capacity. The great importance of this feature you will see more clearly when I explain to you later what we are doing on the Union Loop in the rapid handling of trains. We are accomplishing things there that would be impossible with steam locomotives.

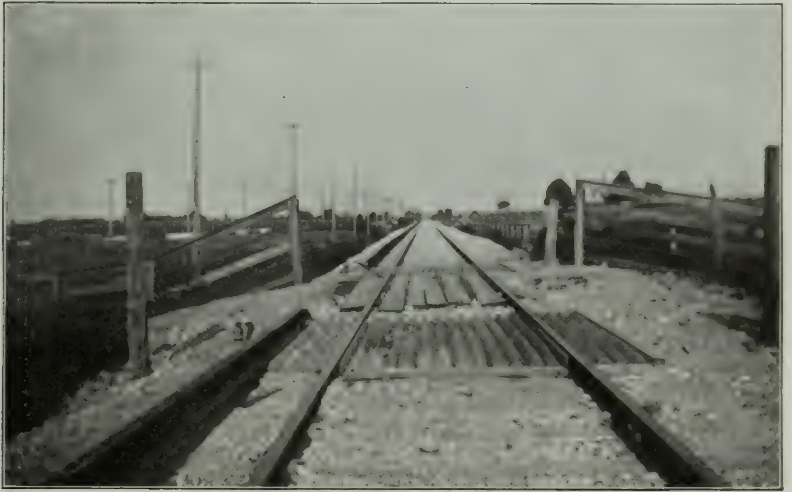
The third item—"Service more attractive to the public generally" is proved by the facts of the absence of smoke and steam and the great reduction in noise, these being especially important in systems passing through the heart of a large city as is the case of elevated roads.

In regard to the use of the third rail systems on inter-urban roads the same *general* considerations apply as to the *economy* of operation, except that trains being less frequent, the economy in the power generation is not so great an item.

There is another field for the third rail electric railway system, which has been developed by the New York, New Haven & Hartford steam road, and that is the use of light trains for suburban and inter-urban service on many of their branch lines.

In regard to fencing the right of way on a surface third rail system, it is interesting to note that the managers of the Albany & Hudson Railway, and the N. Y., N. H. & H. Railway state that injuries due to the third rail are rare, and that with proper signs and fencing the accidents on the systems as a whole are no greater than on any ordinary steam road. From personal observation and experience I can state that a man of ordinary intelligence needs only one good jolt from a railway circuit to make him very respectful in future toward all bare conductors.

A very large inter-urban electric railway system with the third rail equipment is now in operation from the Fox river valley to Chicago, and is known as the Aurora, Elgin & Chicago railway. The right of way is entirely private, except in Aurora and Elgin; the road-bed is of the heaviest steam construction, with stone ballast, stone bridges, and but few grade crossings. The equipment for this road is on steam railway lines, as far as luxury and elegance of appointments are concerned, the cars being equipped with motors of sufficient power to drive the train at a maximum speed of 70 miles an hour.



Country Road Crossing — Third Rail Cut and Connected by Underground Cable

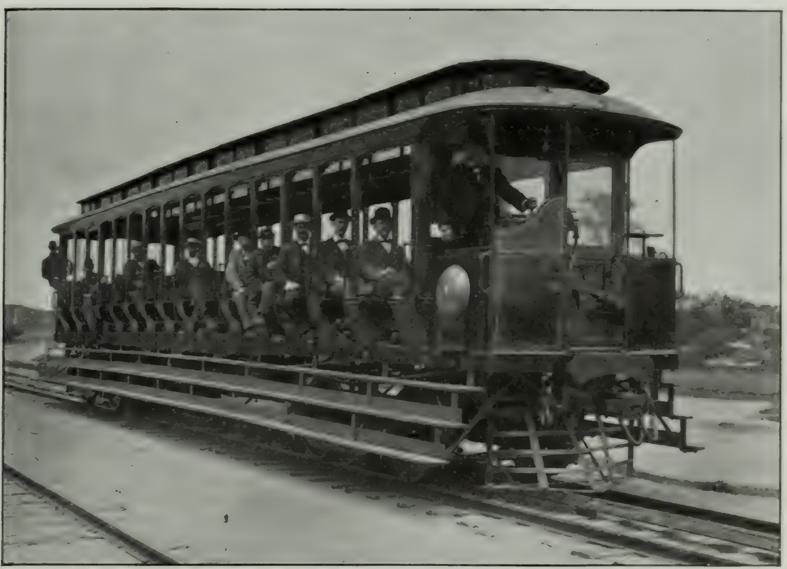
It is perfectly possible to haul the heaviest kind of passenger and freight trains with electric motors, as has been demonstrated by the Baltimore & Ohio railroad, at Baltimore, where they handle through the tunnel, all their trains, both passenger and freight, to avoid the smoke and other objectionable features of locomotives. But to obtain the greatest benefit in the economy possible with the electric system, the service should be such as to employ frequent trains of light weight, which gives a steadier load upon the generating plant. It also has a tendency to increase passenger travel, due to greater accommodation afforded the general public. It is stated by the manager of the Albany & Hudson railway, Mr. Maurice Hoopes, that it is actually cheaper by about 23 per cent to equip an electric railway with a third rail instead of the overhead trolley. In this estimate, the rail figured on is of special composition, giving a conductivity of 8 to 1 as compared with copper. He also states that the cost of *maintenance* is very much lower, and the system more reliable, due to absence of delays, from the trolley coming off the wire and wrecking the line by striking cross spars or pole brackets. This is a difficulty with an overhead trolley that is hard to overcome when running cars at forty or fifty miles an hour.

In designing the original sliding shoe and third rail for the Intramural electric railway, what was required was an arrangement which would be capable of supplying large amounts of current to a great number of heavy trains, without burning of contact surfaces, and which would also operate around sharp curves, over crossings, etc., at a high speed without special attention from the motorman or conductor. That the requirements were met by the sliding cast iron shoe on a steel rail is proved by the wide adoption of the device and the very slight variations in detail that even six years' use has suggested.

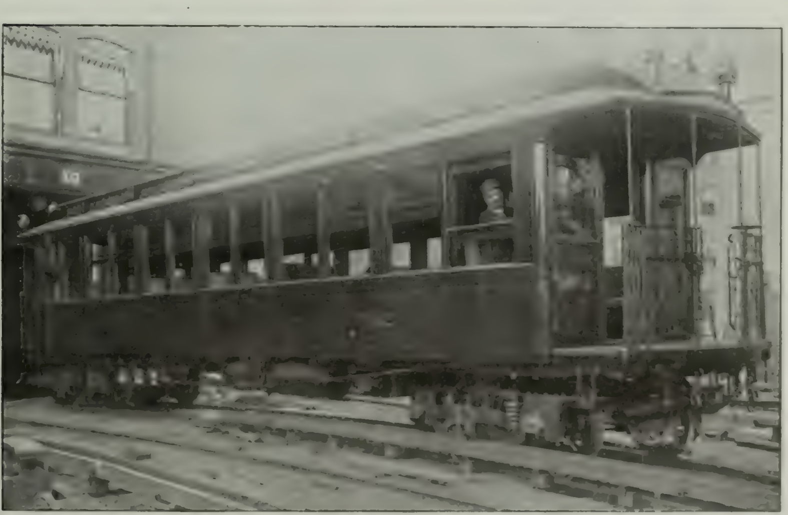
The first shoes experimented with were made of a composition having a large percentage of copper, and in order to insure contact the device was so designed as to allow of the insertion of a heavy coiled spring to force the shoe against the conductor rail. A few days' trial demonstrated that these shoes would wear out with such rapidity as to prove an enormous expense. Cast iron shoes were then tried and with better success, though still retaining the spring, but even these wore out rapidly. It was not until case-hardening the surface and other similar expedients had been attempted, that it was decided to abandon the spring, and we were surprised to find the arcing without the spring pressure was not appreciably greater than with it, and that the shoe lasted practically indefinitely. The process seems to be that after a few hours' run the frictional heat generated by sliding over the contact rail hardens the surface of the cast iron shoe so as to make it resist the wear.

Shoes are running about two and a half years on the Metropolitan Elevated, or about 150,000 miles, and are made of ordinary cast iron. On account of the constant motion of the shoe, due to the inequalities of the rail and the relative movement of the car, the electrical connection is made by a flexible cable, each end being soldered into a terminal attached respectively to the shoe and the main casting. Four shoes are attached to each car, and in this way it is possible to so locate the contact rail as to insure a supply of current for the cars at all points on the road.

Having decided upon a sliding shoe and rail, the next important question was the *location* of the contact rail. Only two feasible positions suggested themselves. First the center of the running track directly beneath the car, and second, on the outside of the running track at a convenient elevation.



New Haven & Hartford Electric Railway, with Third Rail between Track Rails.

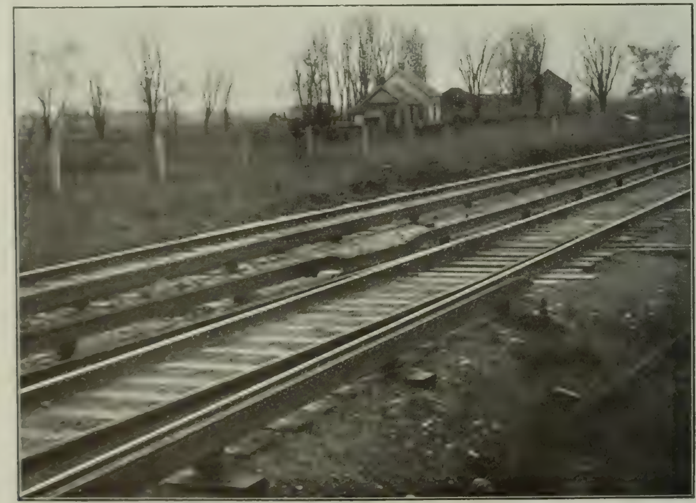


Electric Car with Outside Shoe for Third Rail—Manhattan Railway, New York.

At the first glance the central location seems more natural. When, however, it is attempted to carry such a system through a complicated set of switches, particularly where slip switches are used, as in the yards or crossings, great difficulty is experienced in insulating and at the same time locating the contact rails so as to give a continuous supply of current to the train in passing over the various routes.

Also the distance between the bottom of the motor which is suspended from the truck and the top of the running rail is so small that when crossings occur it becomes very difficult to properly insulate the rail, and at the same time give it mechanical support. Again, the dropping of the brake rigging or any other apparatus, would of course mean its falling directly upon the live rail if located centrally, causing short circuits and consequent interruptions in the system.

Another point to be considered is the necessity at times when the electrical apparatus of the car is grounded, of lifting the contact shoes from the third rail. This is an extremely difficult matter with the shoes located directly beneath the car. On the other hand, the rail placed at the side of the track can be elevated to a height which will enable a thoroughly mechanical design for the insulating block. It also leaves it accessible for repairs by trackmen, and reduces the problem of lifting the trolley shoes to an extremely simple one.



Cross-Over, with Drop in Third Rail—A., E. & C. Ry.

In working out the details for some four-track slip-switch crossings on the Metropolitan Elevated, it was necessary to use movable contact rails, that is, rails which are thrown from one position to another in connection with the track switches. These movable rails were connected with the interlocking levers, in some cases raising and lowering, and in others swinging sideways in order to bring them to the necessary position relative to the various routes over which the cars are intended to pass. We have succeeded even in the most difficult crossings in designing movable rails which work in a thoroughly satisfactory manner, but this could not have been done with a contact rail located in the center of the track.

The use of the ordinary *track* rail for the conductor was largely a matter of convenience in the first case, as rails were the easiest form of steel to obtain in reasonable lengths, and their shape was such as to lend themselves to the various requirements of attaching bonds, angle bars and insulating supports. The price of rails in 1893 when equipping the Intramural was so low that it was cheaper to put in an additional rail alongside the contact rail as a supplemental feeder, than to buy copper for this purpose, and the Metropolitan feeder system, as originally installed, consisted of steel rails, known in the trade as "seconds," bought at about $17.00 a ton. These rails were placed upon insulating supports between the running tracks. The foot walk for the convenience of trackmen, was placed above them, so that to the casual observer nothing is apparent but the ordinary contact rail.

The value of an ordinary commercial steel rail as an electric conductor as compared with copper is about 10 or 12 to 1, with of course the additional disadvantage against the rail of the necessity of the frequent bonding, the rails usually coming in 30-foot lengths. To offset this lower carrying capacity, however, compare rails at $17 per ton with copper at $360 per ton, and it can be seen that one can afford to put in the larger amount of steel required for a given electrical capacity and have a good margin in favor of the rails. With the present price of rails, however, this argument would not hold true. The rails referred to as "seconds," are rails which have been rejected on inspection on account of some defect which makes them unfit for track work, and yet leaves them perfectly good for electric conductors where no mechanical strain is put upon them. A commercial 80-pound track rail has a carrying capacity about equal to an 800,000 c. m. copper cable. In purchasing the contact rails for the extension of the Douglas Park line they were made of steel of a special chemical composition, having a higher electrical carrying capacity than the ordinary commercial steel rail. The composition was obtained after a series of experiments conducted for the Manhattan Railway in New York city, with a view to getting the best possible conductor with a composition of steel that could be successfully rolled into rails.

The use of this composition results in a steel rail so soft as to be unfit for ordinary railway service, but the conductivity is raised so that compared with copper, the ratio is about 8 to 1, as against 12 to 1 for ordinary commercial steel rails.

Experience has shown on the Metropolitan Elevated system that with feeders composed of steel rails they can carry enormous overloads without danger from heating, but there are some necessary repairs and inspection of the bonded joints, which would be avoided by the use of copper cables

On the Northwestern Elevated, in this city, *aluminum* cables have been used at a considerable saving in the original outlay, as this material costs for an equal carrying capacity about 30 per cent less than copper, the relative value as conductors for equal cross-sectional areas being in proportion about 63 to 100 for copper. There are two difficulties which have developed in the use of aluminum cables; one being the fact that the relative expansion with changes of temperature is very great, so that a cable pulled taut in cold weather will have an immense amount of slack with a rise in temperature as frequently happens in this climate, and vice versa. Another point is the difficulty of making the joints where connections are necessary, as the ordinary process of soldering or sweating the joint, as is done with copper, cannot be used.

Here is a chemical analysis of commercial and special steel rails for conductors:

	Commercial Rail. Per Cent.	Manhattan Railway. Per Cent.	Albany & Hudson. Per Cent.	Metropolitan Elevated. Per Cent.
Carbon - -	.47	.073	.09	.09
Manganese - -	.76	.341	.44	.50
Phosphorus -	.104	.069	.088	.100
Sulphur - -	.03	.073	.08	.053

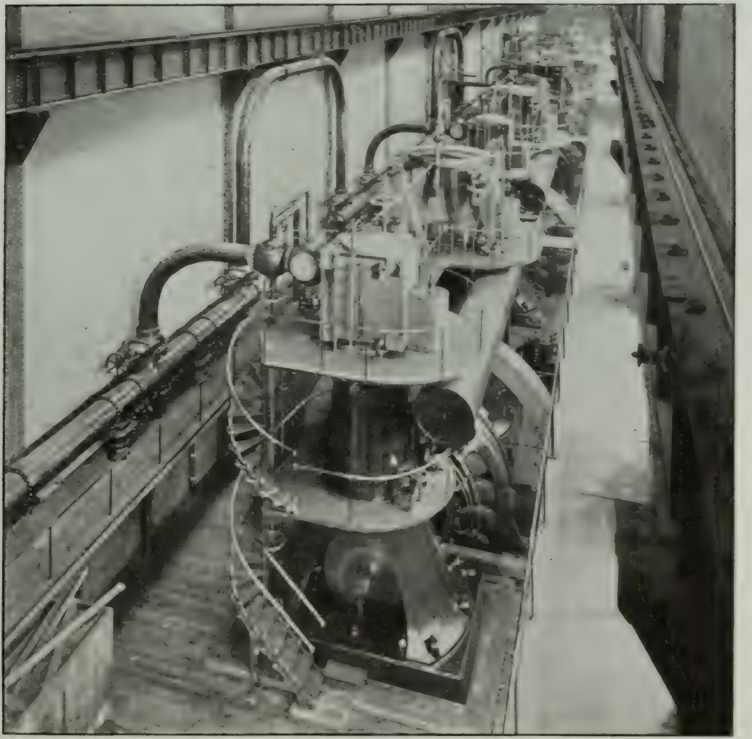
The commercial rail gave a resistance of 18.2 michroms per cu. cm. or a ratio to copper of 10.17.

The Albany & Hudson gave a resistance of 12.9 michroms per cu. cm. and has about 7.25 times the resistance of commercial copper.

One of the most difficult problems in equipping an electric railway system is the proportioning of the total capacity of a power house to the number of cars run, and the sub-division of this total capacity into proper sized units. In order to determine these points, it is necessary to be able to estimate the maximum loads that will have to be carried during the rush hours, and the minimum loads during midday and midnight. The maximum load does not always depend upon the total number of trains run, as in some lines more than half of these trains will be running light in one direction in order to carry the crowds back on their return, or vice versa. On other systems travel is more equal.

Again, the distance between stations, grades over which trains must be operated, and the running time that will be required in order to meet competition with other lines, all enter into this problem.

The question of heating cars is a more serious item than is generally realized, if this is to be done electrically. In extreme weather when all the heater circuits in a car are thrown on, it takes forty per cent of the total current required for the train for the heating.



Power House, Metropolitan Elevated Electric Railway.

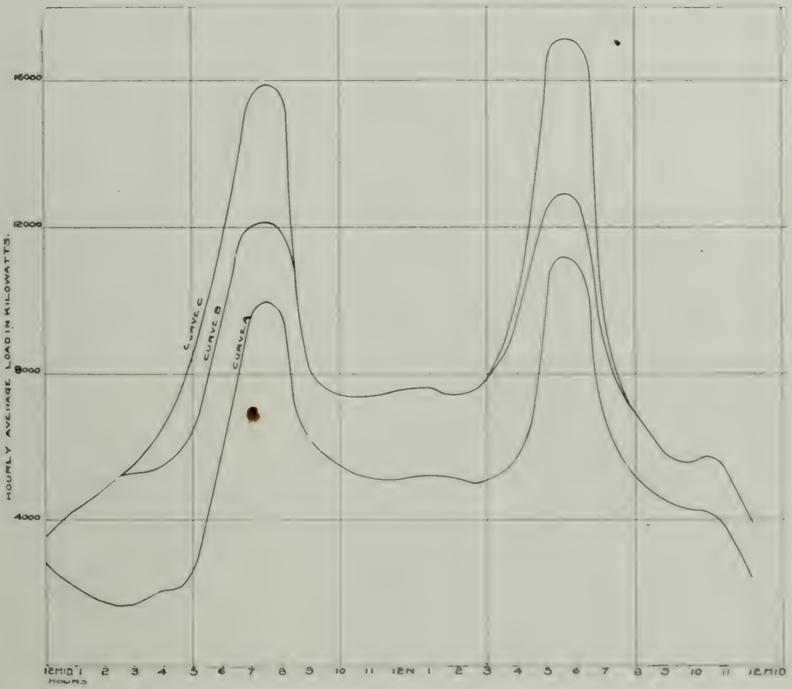
The average amount of current used for heating from November to May, however, is only about twenty per cent of the total used in train operations. In sub-dividing the total capacity of a power house it is desirable to have a single unit, which will carry the minimum light load with reasonable economy, and if the sub-division of the total capacity of the power house into units of this size does not give too large a number of engines, such an arrangement will be found most convenient for repairs, as various parts will be interchangeable.

The load on a power house operating in connection with an elevated railway system, such as in Chicago, varies not only from a maximum during rush hours to minimum during off hours, but also momentarily during the starting and stopping of trains, these fluc-

Salt Creek Bridge — Concrete Construction.

Desplaines River Bridge.

Distributing the Conductor Cable.



Typical Load Carried at Power House for 24 Hours.

tuations being most violent when the least number of trains are in service. Under the worst conditions this rate will vary from 300 amperes to 4000 in fifteen seconds, or the reverse. It is necessary, therefore, that all the engine's parts should be especially heavy, particularly the fly wheel, in order that sudden changes in the load should not interfere with the proper regulation of the engine speed.

To take up such violent fluctuations, storage batteries are sometimes used, as on the South Side road.

Diagrams herewith show a typical load curve at the power house.

Curve A is that of the trains in service. Curve B shows the additional amount of energy for heating the cars, with heaters only partly turned on during the rush hours, while Curve C gives the

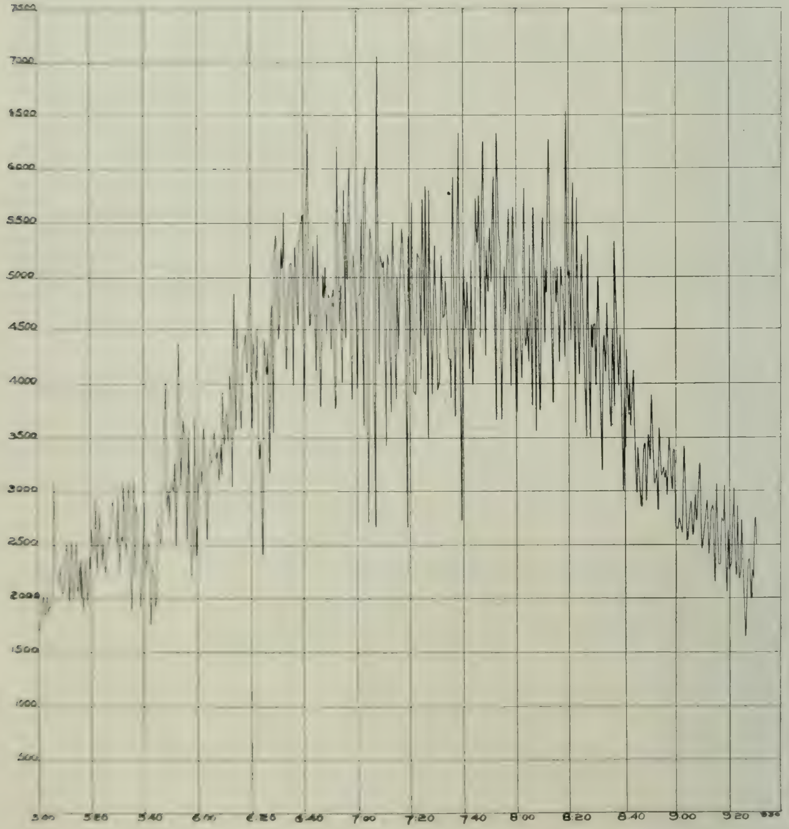


Diagram Showing the Fluctuations in the Consumption of Electric Energy, at short intervals, from 5 a. m. to 9:30 a. m., ranging from 1700 Amperes to 7000 Amperes.

total load with heaters turned on full during the rush hours. The high peaks of the curve occur at the rush hours of travel.

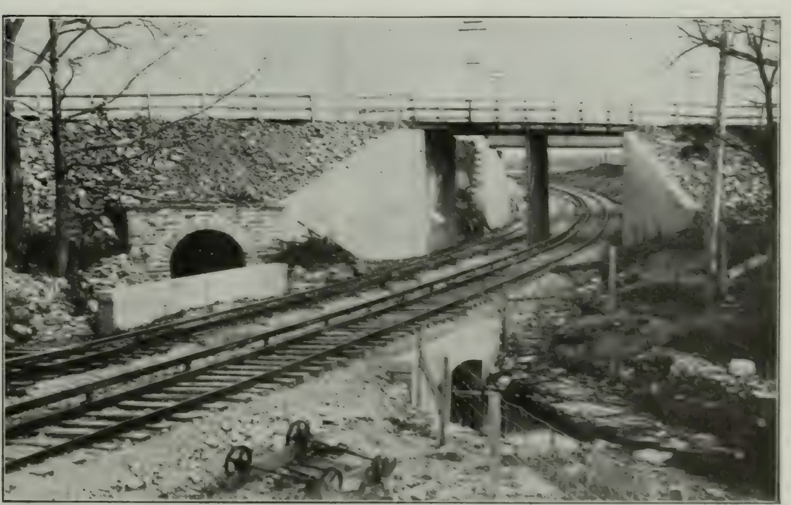
The second diagram shows the violent fluctuations in the demand for electrical energy for operating the trains.

The Aurora, Elgin and Chicago Electric Railway probably affords the best example of heavy high-speed electric railway work to be found in the world.

Between Wheaton and Elgin and Wheaton and Aurora the country is without any large villages, though it is a thickly settled and productive farming country all the way. The syndicate controlling this company has also acquired control of the electric lines connecting Aurora, Batavia, Geneva, St. Charles, Elgin and Carpentersville.

The chief interest on the road to the electric railway engineer, however, aside from the local situation, is the solidity of the construction, and the high speed at which trains are operated in this service.

The motor equipment is designed and guaranteed to maintain a car at a maximum speed of 70 miles per hour on the level at normal voltage on the third rail. To insure this high speed the motor equipment is the heaviest yet put on cars for this class of service. Each car has four 125-H. P. General Electric motors. The cars and trucks follow M. C. B. standards quite closely. The General Electric multiple-unit or train-control system is put on all cars. Cars are run either singly or in trains. In case trains are made up consisting of as many as three cars, one of these cars has no motors, otherwise every axle on the train will have a motor.



Under Grade Crossing and Concrete Culvert.

The track construction is of the most thorough character and renders it possible to attain a high maximum speed.

From Chicago to Wheaton the line is double-tracked. From Wheaton to Elgin and to Aurora single-track lines are built. However, on the single track the sidings are of considerable length to avoid loss of time at the passing points.

The road uses the third rail, except in the towns of Elgin and Aurora, where it does not run over a private right of way. The third rail weighs 100 pounds to the yard, and is located in the standard position outside of the track rails, as adopted by the elevated roads of Chicago and other cities. The conductivity afforded by this 100 pound section of T-rail is sufficient so that no copper direct current feeders will be necessary. The power is transmitted at 26,000 volts over three-phase lines supplying sub-stations. All these sub-stations feed direct into the third rail, which is not normally sectioned, but are tied together, so that the sub-stations assist each other. The power house is at Batavia, on the Fox river. From the power house three three-phase 26,000 volt aluminum feed lines run out, with the arrangement such as to give duplicate feed lines to most of the road. One line runs directly from the power house to sub-station 1, at Aurora; from there to sub-station 2, at Warrenville; and thence to sub-stations 3 and 4, on the main line. Another line runs directly from the power house to the Warrenville sub-station, where it joins the high tension line from Aurora. Another high tension line running direct from the power house to sub-station 5 also runs northwest to feed sub-station 6, and con-

Distributing the Conductor Wires.

tinues east to sub-stations 3 and 4. Sub-stations 3 and 4 are therefore supplied from two high tension lines, one of which comes from the power house by way of sub-station 5 and one by way of sub-station 2. The high tension lines, therefore, practically form two loops, so that in case of a break anywhere on the high tension lines, current can be supplied from the other direction, except in case of sub-station 6, which for the present has only one source of supply. The high tension lines are carried on poles 35 feet to 40 feet high in the country, and 50 feet to 60 feet high in the towns through which the road passes.

About a year ago a French engineer visited Chicago, on a tour of investigation of the rapid transit systems of this country. He was taken one evening, during the rush hours, to the junction of Fifth avenue and Van Buren street on the Union Loop, and was astonished at the rapidity and frequency of the train movements. He could not believe that this could be the normal daily condition.

He stated that in Paris the law forbade his railway company from operating its trains at less than three-minute intervals, and these intervals were maintained by means of block signals. His road was a third rail system running on a fenced right-of-way on the surface and extended out through one of the suburbs much as the Lake Street Elevated goes through Oak Park.

To give some facts as to what is actually being done daily on the Union Elevated Loop, I will state as follows:

During the month of January, 1903, 1,523 trains were handled every 24 hours on the Union Loop; or

In other words, one train every 56 seconds, for an average during the 24 hours.

During the rush hours from 5 to 7 p. m. 212 trains are handled, or one train every 33 seconds.

During the fifteen minutes from 6:00 to 6:15 p. m., forty-six trains are handled, or one train every nineteen and one-half seconds.

During fifteen minutes in the a. m. rush, fifty-four trains are handled, or one every sixteen and one-half seconds.

During one hour in the a. m. rush, we are handling 187 trains through this crossing, or one every nineteen seconds.

We are loading on the Union loop on an ordinary week day 54,000 people from 5:00 to 7:00 p. m., and 40,000 from 5:15 to 6:15 p. m.

To give an idea of the wear on the various frogs and crossings, there are 27,880 wheels passing through this junction every twenty-four hours.

CLXIX.

TELEPHONE SERVICE.

By S. J. Larned, Supt. Chicago Telephone Co.

Read before the Chicago Electrical Association, March 20, 1903.

I will discuss briefly what seems to me the chief value of telephone service in the daily work and play of the community; what it does that nothing else can do, and what it does better than any other agent can do it, and then a word or two about good and bad service, and the organization and methods employed to make it good.

There is probably no one characteristic of civilized human life to-day more pronounced than the readiness with which we adopt new facts, new ideas, new inventions, and turn them to the most account. We develop them, find new uses for them, discover necessities that we never dreamt of and re-arrange our whole collection of habits so that the new comer shall have a place, and there has been no one factor more promptly adopted and made much of than the telephone. Bell's invention bears about the same relation to the telephone system of to-day that the invention or evolution of the art of writing does to the modern postoffice system, and yet one process of development has occupied twenty-five years and the other a few odd thousands of years.

The telephone belongs to that class of the servants of mankind that have done the most for his intellectual and material advancement, for the history of what we call modern civilization is the history of the development of the arts of communication, beginning with articulate speech and the art of writing, and followed by the slow and hesitating developments of the means of transportation whereby man or his property or his written messages can be moved from place to place.

A hundred years ago a Boston man, associated socially, politically, or in a business way with others in New York or London, or Philadelphia, could hardly keep in touch with them. He was dependent on correspondence, painfully written out in long hand and transported by primitive means so slow that not many letters could be exchanged in a year's time; or he could with a great deal of preparation and personal discomfort, make the trip himself and enjoy the advantage of the more satisfactory face to face conference. But a great advance in all the machinery of communication was soon to be made. It began when the railroad and steamboat made traveling easier and quicker, and expedited the interchange of letters; then came the telegraph that gave wings to the letter and made a rapid interchange of messages possible, without regard to distance, and lastly the telephone, which within certain limits, has annihilated distance and gives us most of the advantages of a face to face or at least, an ear to ear conversation, without the transportation of the physical body. It is this, I think, that gives the telephone its chief value, in that it provides a time saving substitute for the personal interview. It allows of a kind of communication or interview that was formerly impossible. The carrying on of a dispute even by telegraph, for instance, however much it might spare the tempers of the disputants, would certainly delay the settlement of the mooted point. But by telephone we quarrel and argue with people miles away, and lose breath and temper perhaps, but we do get points settled and instructions given and explanations made in a day, that without the telephone, would have occupied our time for a week. It is possible, with hardly an interruption to routine, or without even temporarily dropping a subject from the mind, to consult and advise with people at a distance. One can move promptly, move advisably and secure better results, than when such correspondence must be carried on by mail or telegraph, or the matter laid aside till a personal trip can be made.

It is not a labor saver (it is a pity that term ever crept into use to frighten the classes who have labor to sell), it is a labor multiplier, as all modern machinery is.

But all business communications do not involve an exchange of ideas, or a conference, as it were. Perhaps the greater part of them are simply orders for goods, directions for work, etc. The mail and the telegraph carry the larger part of such communications but even of these, the telephone gets a share because of its wide distribution, its speed and its cheapness.

The distribution is not quite universal as yet, but the world is improving in that respect and it is seldom that one finds it impossible to reach by telephone anyone with whom he wishes to talk. Your butcher, your baker and your candlestick maker are all on the wire and even your office boy or your foreman can generally be reached at home if you need them. The man without a telephone to-day is a hermit, almost as isolated as if he had forgotten to make a door in his house or store.

The statement as to speed and cheapness may be challenged by some people for a hypercritical attitude toward the telephone service is somewhat popular, and I do not want now to go into extended argument on these points, but the fact remains that in any large city you can in four cases out of five get the ear of the person with whom you wish to talk, within a minute or two at most, and the same man who is impatient at a three-minute telephone delay will cool his heels for fifteen minutes outside the office door of the man he is after without a thought of complaint. The readiness with which business men will grant an interview by telephone, while they deny admittance to callers in person, is often commented on.

The extent to which the telephone has supplanted other message carriers, even in the second class of messages referred to, is proof of its economy.

I need not tell in detail the story of the gradual extension of the use of the telephone from the few scattered private lines of the year or two following the invention, down to the hundreds of thousands of instruments of to-day, bound by cables and switchboards into one huge complicated machine, reaching every nook and cranny of the country. I want to take all that for granted and jump at once to the work which the perfected telephone exchange does in our community life.

If we classify all telephones as to the nature of the places in which they are located, the group of residence telephones will be the biggest. In Chicago over 20,000 families find a telephone at home worth while. With the men of the house, its principal value is to establish a link between house and office, putting the business man within reach in case of accident or emergency and often enabling him to stay at home, when without such a connection he would have to be on duty. In sickness he is not isolated and telephones are often placed at a bedside to allow some unfortunate to still conduct his business, though he may be on his back.

But to the real head of the home, the connection with the grocer and the butcher is the all-important one, and to the market men this business is so important that they have sometimes paid for telephones in the houses of their customers for the sake of getting it. In some cities, notably San Francisco, an extremely cheap service known as kitchen service, has been established, and is much used. It is primarily intended for marketing and the stipulation is made that the telephone must be located in the kitchen. It is a one-way party line service, there being no bells placed on the instrument, and as its name implies, devoted to the stocking of the household larder.

Emergency calls for fire or police protection, or for the doctor, are not as frequent as the market and social calls, but perhaps count for about as much in importance. Probably more than half of the fires in most large cities are reported by telephone.

Ingenious householders have found innumerable other uses for the telephone never originally thought of. The operator many times gets the request "Please ring my bell at 6 o'clock to-morrow morning;" 5,000 times every day in Chicago she is asked for the time of day; election and prize fight results, foot ball and base ball scores are asked for and reported. Many attempts have been made to allow telephone patrons to listen to operas, concerts and church services, but without any permanent success. I have heard of people taking French and German lessons over the telephone.

In no other class of service are the demands and uses as varied as in the residence service. In exchanges where they predominate, the load line is very different from the more purely business exchanges, and it indicates in a way the habits of the inhabitants. The load comes on earlier and the maximum demand comes at marketing time about 9 a. m., and then falls off and continues at a pretty uniform rate till late in the evening. A little spurt is noticeable at about 5 p. m., when the man of the house calls up from the office to explain why he cannot come home to dinner, or to announce that he is bringing four or five friends with him.

The interpretation of these fluctuations in the load line is often interesting, as for instance, a pronounced drop in the load line of a Kentucky exchange which occurred every day at 11 a. m. and was found to be due to a convivial habit of the natives, where everybody drops work at that hour and goes out to take a drink.

The majority of residence telephones are connected up on party-lines, their light traffic hardly requiring the exclusive use of a pair of wires for each one.

Closely allied to the residence service is the system now becoming popular in most of the large hotels. A private switchboard is set up in the hotel with a telephone connection to every room and trunks to the city exchanges. The newly arrived guest, in his very bedroom, at once becomes a part of the great telephone community, one of the get-at-able people of the city, and is presented with the keys of the city more really and effectually than ever were old time heroes who were honored by that interesting old ceremony. The ubiquitous instrument on the wall enables him to announce his arrival, to receive calls, to talk with his family in a distant city, or to order from the bar the particular concoction which he most prefers. And even when he, or for that matter, any of the natives of the city, are on the street, away from their moorings, the thousands of public telephones scattered on every corner, still keep them in instant touch with their interests, if need be.

To the merchants big and little, the telephone is the door-way through which a large portion of their customers enter; with some by far the biggest part of their trade comes to them over the wire. Gradually they have all come to appreciate the importance of this bond of union with the outside world. Many who a few years ago allowed their customers to crowd and push one another in their efforts to get into them over one overcrowded telephone line now advertise with great prominence the special facilities they have provided for such business, with clerks who devote their entire time to telephone orders.

Those who carry small stocks depend upon it entirely for replenishing, in case of sudden calls.

A few years ago when the lumber business was a little smaller, a lumber merchant who received an order for a kind of lumber which he did not have in stock, would go to the telephone and say to the operator, "Give me the district." He was then connected with one lumber man after another until he found the required amount of that particular stock.

In the offices of the various professional men, lawyers, physicians, etc., the use and dependence upon the telephone is nearly as great. The doctors, of course, are slaves of the telephone, being always at the beck and call of their patients. For their special behoof, a form of portable telephone has been devised that can be carried from room to room, so that eating, sleeping or in his office, the doctor may always have his telephone at hand.

The big corporations would hardly be a possibility without the telephone systems, which bring all their multitudinous heads and branches within talking distance of one another. Were they to be made dependent once more on old time methods of inter-communication, they must break up into smaller, simpler parts.

One of the vital organs of their being is the private telephone exchange; designed primarily to afford quick intercourse between the individuals within the organization, it has also become a clearing house for most of their transactions with the outer world.

In construction a private exchange is simply a general exchange in miniature, though when one considers the private exchanges that serve the large railroads and the packers, or a store like Marshall Field's, the term miniature is perhaps inappropriate.

The relations of a private operator to the people she looks after are direct and personal. She must know each man's name and part in the organization, and be able to connect inquiring strangers to the proper person. She must know who is to be allowed to speak to the august head of the establishment, and who must be satisfied with the ear of some one lower in the line. She must know the office habits of all her people, where they are to be found at any hour of the day. She gets to know their voices, their dispositions, the numbers they generally call; she is a confidential telephone clerk to the entire establishment, and a calamity overwhelms the place when she marries the book-keeper, and a new operator has to slowly learn the ropes.

Private exchanges and private operators are by no means confined to the giants in business. Wherever a business gets beyond the one man stage, there is a field for the private operator, and that form of service is rapidly growing in popularity. In New York

City the number of private operators by far exceeds the operators employed in the central exchanges.

Most telephone men feel that the general tendency of the demand to-day is for a more personal service, rather than for a self-operated mechanical device, however well designed. The busy man prefers to have a professional attendant to operate for him the machinery that he uses, whether it be a typewriter, an elevator, a street car or a telephone switchboard. Conductorless street cars have never been popular, and I doubt whether operatorless switchboards will ever be more so. I do not mean that I disbelieve in mechanical appliances, calculated to increase the working range of any individual. We can say with certainty that in the future, operators will do more and more of their work through the use of just such appliances, but ideal service will still require the interposition of a trained operator between the general user and the wonderful, intricate machinery of a telephone exchange.

Ideal service though it can never be quite attained, is the ambition of the operating department of a telephone company. People differ as to the essentials of good service, but I will venture to set down the following points as in my opinion most vital, from the user's point of view.

The exchange should include as patrons, everyone with whom one might wish to converse.

Calls should receive uniformly prompt response from the operator.

Connection with the person or telephone called for should be made rapidly and accurately and should not be interrupted.

Communication should not be prevented by busy lines.

Communication should not be interfered with by the apparatus getting out of order, or if such trouble does occur, it should be promptly remedied.

And last but not least, the treatment of patrons by employes should be courteous. The converse of this is true but is not so easily controlled by the telephone management.

The requirements are ideal and service is good if it only approximates them closely.

That the first point is the most important one is, I believe, unquestionable. The value of the service to any individual depends directly upon the proportion of his correspondents who can be reached; and quite apart from a natural desire to increase its business, the management of a telephone company is neglecting its field if it does not attempt to place its telephones in every house that has a roof to shelter them.

And as for the citizen who pretends to have any dealings with his fellow men, he owes it as a duty to society that he should connect himself with the telephone exchange. How many times have each of you been put to trouble and annoyance because someone whom you wish to reach in an emergency, has neglected this, and isolated himself.

It is sometimes stated that the installation in Chicago of a vast number of telephones at low rates on party-lines, has been unfair to the larger users of the service; that it has perhaps been a boon to the small users who could not afford a better service, but that the others suffered, drowned as it were in the ocean to which their little pool had suddenly grown.

But this is not an age in which people, business people at least, care to limit their intercourse to a small and select circle. The telephone aristocracy, if I may call it such, has suffered in the way a newspaper would suffer if its readers were doubled; or as a retail store would suffer if increased multitudes were brought to its doors each day.

Even if they were jostled and pushed a little by the newly admitted hoi poloi, and subjected to a few more troubles in their telephone service, which has really not been the case, it would have been more than made up to them by the increase in their clients, customers, etc., brought within reach.

But when people generally speak of good or bad service, they have in mind not its value to them but some of the other points I have mentioned as essentials.

The service is most often gauged by the way in which calls are answered by the operator, by the promptness with which she responds and by her general bearing and attention and courtesy.

The standard of service generally set requires that the time of answering, i. e.—the interval between the picking up of the telephone and the response of the operator—should not average more than six or seven seconds. But a good average alone is not sufficient. A user may have been answered in three seconds on twenty consecutive calls, but he is apt to forget that part if on the twenty-first call he has to wait a minute.

The answering must then be uniform. The generally accepted standard on this point is that from 90 to 95 per cent of all the calls must be answered in less than ten seconds. The uniformity of the service is affected principally by the nature of the operator's work. The two factors determining the load upon her, are the number of calls she has to answer and the operations or talking required to dispose of each call. The service is bettered very much more by decreasing the second factor than the first. As a matter of fact, every one of us is more alert and active, and accomplishes things with less effort when he is busy and pushed, than when things are not coming his way rapidly, and if we decrease the number of calls that an operator has to answer, and give her time to lean back and fold her hands between calls, her attention is sure to lag. But by paring down unnecessary phrases that she uses, by machinery to cut out certain manual operations, by providing easily read signals to keep her posted on various phases of the connection, the amount of time that she must give to each call is so reduced that even though she receives simultaneous calls from three or four patrons, each one can be answered with reasonable promptness.

The work of an operator is not easy, and the requirements of a good operator are many. She must have a good voice and a quick ear; she must be alert, active, even tempered and adaptable, for though one moment she may be hearing the imprecations of a man to whom she has just had to report a line busy for the fifth or sixth time, she must turn instantly perhaps, to answer a lady to whom her voice must show no trace of impatience.

Her first learned and most often reiterated rule must be one of patience and courtesy. The most rigid discipline, of course, must be insisted upon, for inattention follows the least appearance of a free and easy spirit. Plenty of calls to answer, is the greatest aid to good discipline, for the old saw that couples up Satan and mischief and idle hands, is as true of telephone operators as of the rest of mankind. Besides this, a military system of responsibility is carried out, the operators being divided into small groups of nine or ten, each captained by a supervisor, who in turn is responsible to a chief operator.

Though an operator is required to concentrate her whole attention on her work while on duty, she is given frequent resting spells throughout the day in comfortable rooms provided for that purpose in each office, so that the work is not, on the whole, trying.

The applicants for positions are always in excess of the needs and the successful ones are selected by examinations. This provides the raw material for an operating force, composed for the most, the best part generally, of young Irish-American girls. Weeks and months of patient teaching and practice are needed to round them into form, and after a couple of years service, matrimony claims them, and new recruits must be trained for their places.

Courteous treatment of patrons by employes, and vice versa, are without question, things of which the exchange management must take cognizance; but perhaps the treatment of patrons by patrons is nearly always their own affair. Nevertheless, I want to voice a protest against a growing habit which is, I think, the grossest kind of an imposition upon the victim of it.

Mr. Brown wishing to talk to Mr. Jones, tells his office boy to get Mr. Jones on the telephone. Mr. Jones is called, perhaps taken away from important work, and when he gets to the telephone, instead of finding Mr. Brown ready to talk, is told to wait a minute—

Mr. Brown wishes to speak to him. My own practice on receiving such a call, is to promptly hang up my telephone, instead of waiting, and get what little satisfaction I can out of the knowledge that Mr. Brown is also wasting a little of his time. If I ring my neighbor's door bell I expect to be considerate enough of his convenience to be at his door when he opens it, and do not send a small boy to ring it a minute or two in advance of my arrival.

The next feature of good service that I mentioned, was the absence of busy reports. The most often complained of, and least often deserved fault that the exchange manager bears, is that of false busy reports. While too frequent busy reports are a decided defect in service, it is one, only in a small measure, controllable by the telephone management. The only remedy is a campaign of education among those insufficiently provided with telephones. But they can never be eliminated. In Chicago, about one call in five is unsuccessful because of a busy line.

Telephone men have adopted the railroad use of the word "traffic," to describe the amount of business, the number of telephone calls or conversations carried on in a fixed time.

Traffic counts are made at frequent intervals on particular lines or in total, to point out overloaded or underloaded lines, or operators, or exchanges. These counts show in Chicago a total of more than two-thirds of a million conversations per day.

Faults in the service, due to defects in the apparatus and lines, are, unfortunately always numerous, and the maintenance force of an exchange is always a large and busy one. Of the millions upon millions of parts comprising the machinery of the Chicago exchange, it is small wonder that a thousand or more go wrong in the course of every day.

In various ways the knowledge of the mishap filters through to the repair department; some cases are discovered by the operators, others reported by the subscribers.

They must first be diagnosed by the tester, whose work in many respects is analogous to that of the family physician. He first inquires as to the symptoms, thumps the patient two or three times with positive or negative or alternating current, listens to his voice and decides, too often perhaps, that the ills complained of are imaginary.

But having discovered an actual trouble, he turns it over to the proper specialist — the switchboard man, the underground man, or the line and instrument repairman.

The work of these men must be checked and carefully tested after the trouble is cleared. Accurate reports as to the nature of the trouble are made and tabulated so as to indicate prevailing difficulties and point out unreliable types of apparatus. The interval of time between the reporting and the clearing of the trouble, is also noted and tabulated.

The value of all such data of course, is in pointing out definite lines along which improvement may be made and preventing a self-satisfied assurance that conditions are good enough as they are.

Every business house must keep posted as to the quality of the stuff it is selling to the public, and a telephone company must go to particular pains to discover the real facts as to the kind of service it is rendering. It might be supposed that its patrons could be depended upon for such information, but as a matter of fact, about 98 per cent of them take everything for granted, and make absolutely no expression of satisfaction or dissatisfaction. Of the remainder, a few report such difficulties as they may encounter from time to time; another few apparently never encounter anything but.abuse or lack of attention from the incompetent and idle employes of the company.

Another very much smaller lot will occasionally give a word of commendation.

In order, therefore, that the record shall not be entirely blank or black, the telephone company is obliged to learn for itself what is being served out to the public. So a considerable force of men and girls is constantly at work, making hundreds of test calls of every description daily, or standing, stop watch in hand, beside patrons who are making calls, timing the answering, noting errors, busy reports, etc., and the thousand and one details of the service.

These results regularly tabulated are a fair index of the general trend of things. A relaxation of the discipline in any office, due perhaps to an inefficient manager or chief operator, is very soon indicated by the tabulated tests.

To the telephone man it sometimes seems as if all the pent-up impatience of humanity finds outlet at the telephone.

I suppose others whose occupations bring them in constant contact with the general public may have somewhat the same feeling, but it is a fact that many people ordinarily reasonable and courteous, become absolutely unreasonable over telephone annoyances that are as commonplace and unavoidable as the accidental jostlings one is subject to on a crowded street.

This is due, I think, to the impossibility of seeing and knowing all the attendant circumstances. We send a call out over the wires for a friend and cannot follow it through all the intricacies of wire, cable, switchboard, etc. It is easy to imagine if anything goes astray, that some malevolent power at central is thwarting us. It is no unusual thing for a man to work himself into a passion over an inanimate piece of wire that has unfortunately broken, and attribute all of his troubles to the spiteful operator.

Perfect telephone service, that is, service in which each one always gets what he wants and "gets it quick," is as impossible as in any other field of human effort, for we are dealing with a machine, more complicated and with a greater number of parts than any other in existence. Moreover, the parts are distributed all over the land, tied together by mere threads of copper, exposed to the disturbing influences of mankind and the elements, and dependent for good working upon the proper co-operation of everyone concerned—from you who originate a call, down to the irresponsible office boy, or ignorant domestic who may answer it.

ADDENDA.

TELEPHONE INVESTMENTS.*

It may not be out of place to call attention to a few phases of the telephone business which do not generally receive due consideration from the investing public, and which are entirely ignored by those who clamor for the public ownership of telephone and telegraph facilities.

The nature of a railway is such that almost the entire property owned by it is in incessant use. There may be a small mileage of sidings and spurs, which are useful and profitable during only a few months of each year; but the main lines, branches and passing, or yardage tracks, are in constant employment for the handling of equipment or the moving of freight. The larger the amount of money invested in permanent plant, the larger, in general, is the utility of every part of the property.

How is it with a telephone company? Take the American Telephone and Telegraph Company as an example. In 1902 the average subscriber made only seven and four-tenths calls per day. Suppose each call consumed five minutes—which is unlikely—it would appear that each of 1,020,647 instruments was in use only thirty-seven minutes in every twenty-four hours, and the rest of the time was idle. Not only that, but wages were being paid for twenty-four hours a day. The non-use of the plant in no way reduces the cost of maintaining it—poles rot out about so fast and wires call for a certain amount of attention all the time.

It is almost impossible to convince the people that it is worth money to hold a costly plant at all times ready for a service that is actually demanded only seven and a half times a day by the average subscriber.

Though the actual use of the plant may be small, its potential use must be sacredly regarded. Hence the vast extensions of capital for additional lines, additional switchboard capacity, and every adjunct of modern telephone science. And all these things inevitably multiply the labor, superintendence, maintenance, and interest items, which are so great a drain on revenues.

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* Abstract from *Pit and Post*, Chicago, by courtesy of Knight, Donnelley & Co.

It follows that the early years of a telephone enterprise—meaning by the word "early" the period during which the original plant is sufficient and efficient—are apt to be relatively the most profitable. That is to say, the large percentages of profit do not usually persist after a company enters the era of writing off the cost of obsolete switchboards.

At the present stage of affairs it is premature to be too optimistic about the "automatic" systems that are so loudly exploited. On a small scale they seem to be highly efficient, just as the manual-board system is; but there are no very large automatic exchanges of long experience, no mass of statistics from which to deduce conclusions as to the tendency of unit cost under varying "densities" of service, and no conclusive guide as to maintenance, cost, interest charges, and so on through the list.

As an interesting illustration of what has been said, we may make a cursory analysis of the reports of the American Telephone and Telegraph Company, taking the figures of the Treasury Department Bureau of Statistics, reprinted from the "Statistical Abstract" for 1902, page 419. The comparative statement for eight years follows:

	1902.	1901.	1900.	1899.	1898.	1897.	1896.	1895.
Exchanges......	1,411	1,348	1,239	1,126	1,025	967	927	....
Branch offices...	1,594	1,427	1,187	1,008	937	832	686	....
MILES OF WIRE.								
On poles........	823,193	627,897	509,036	396,503	327,315	286,632	260,324	....
On buildings....	17,947	16,833	15,087	15,329	13,776	12,594	12,861	....
Underground ...	883,679	705,269	489,250	358,184	282,634	234,801	184,515	....
Submarine.......	4,200	4,203	3,404	2,973	2,675	2,818	2,028	....
Total miles	1,729,019	1,354,202	1,016,777	772,989	626,400	536,845	459,728	....
Total circuits....	592,467	....	422,620	....	295,904	....	237,837	....
Total employees	40,864	32,837	25,741	19,662	16,682	14,425	11,930	....
Total subscrib'rs	1,020,647	800,880	632,946	465,180	384,230	325,244	281,695	....
Rentals.........	....	$2,647,909	$2,427,037	$1,714,526	$1,610,855	$1,597,959	$1,350,032	$1,475,850
Capital..........	....	104,650,600	89,100,500	25,886,300	....	....	....	....
Gross earnings..	....	11,606,816	9,534 499	7,687,381	5,448,701	5,130,844	4,538,979	4,775,444
Net earnings....	....	7,398,285	5,486,057	4,270,508	4,393,966	4,169,674	....	....
Dividends.......	....	5,050,023	4,078,601	3,882,945	3,882,945	3,682,948	....	....

On examination it is seen that during the seven years, from 1896 to 1902 inclusive, the total number of subscribers increased 262 per cent, and the number of employes increased 242 per cent, or almost in the same ratio. The miles of wire increased 276 per cent—about in the direct ratio again. The circuits showed a gain of 149 per cent, and the increase in exchanges and branches was 185 per cent, exhibiting the tendency of capital account and expenses to keep pace with the growth of business. It is seen that capital has grown at an average rate of 100 per cent a year since 1898, but the average rate of increase in gross earnings for the period 1894 to 1901 has been only 20.05 per cent and in net earning only 15.05 per cent. The amount paid in dividends (not the rate on the stock) has increased only 7.5 per cent yearly in the period under examination; but considering the great extension of capitalization the increase should have been more marked, and doubtless would have been, but for the fact that expenses tend to vary directly as the growth of business and not inversely, as is the case in the carrying industry.

CLXX.

THE DEVELOPMENT, EQUIPMENT, AND OPERATION OF THE SUB-STATIONS AND DISTRIBUTING SYSTEMS OF THE CHICAGO EDISON CO. AND COMMONWEALTH ELECTRIC CO.

By Ernest F. Smith, M. W. S. E.

Previous to about 1897 no sub-stations or storage batteries were employed in connection with the operation of these systems, the current for the various kinds of service being at that time ('97) distributed direct from four central generating stations by means of 230-115 volt Edison three-wire feeders, 1000 volt, 125 cycle, single phase alternating current circuits, direct current series arc circuits, and a few 500 volt direct current power circuits. Of these four generating stations, two were comparatively small three-wire direct current stations located in the outlying residential districts beyond the then economical range of distribution from the other two large central stations ideally situated near the electrical center of the system, one at Washington street and the other at Harrison street, on the Chicago river.

At that time the annual coincident maximum load carried by the Edison system had not exceeded 9500 K. W., of which 49 per cent was carried by Harrison street, 38 per cent by the Washington street station, and 13 per cent by the Oak street and 27th street stations, (the latter two being the small generating stations already mentioned, one located at Oak and north Clark streets, and the other at 27th street and Wabash avenue). At that time 68 per cent of the generated maximum load was generated in the form of low tension direct current distributed directly from the station bus bars to the Edison three-wire direct current underground network of Edison tube mains through Edison tube feeders ranging in size from 206,000 c. m. to 1,000,000 c. m., and of a maximum length of about 6600 feet from the bus bars of the generating station from which they received their supply. In order to maintain normal pressure at the ends of these long feeders, although they were necessarily of large cross sectional area, it was necessary to either operate them on an auxiliary bus carrying a much higher pressure than the main bus, and this often at the expense of running a lightly loaded unit especially for that purpose, or to connect in series with each such feeder a three-wire booster set consisting of low voltage generators operating to boost the pressure in each leg of the feeder.

These methods were necessarily uneconomical and undesirable, and involved an excessive investment in feeder copper in order to distribute even over the very moderate radius of one mile, beyond which it became necessary to install and maintain small inefficient non-condensing generating stations to serve as centers from which to distribute current to the same inter-connected, three-wire network of mains within its own limited territory.

This plan was only practicable from the standpoint of comparative investment, in thickly settled territory where the available load within the prescribed radius was sufficient to warrant the investment involved in the installation and equipment of a low tension, direct current generating plant and distributing system ; and in all cases where these conditions could not be met, the incandescent lighting business was, at that time, provided for by means of single phase 125 cycle 1000 volt alternating circuits employing the house-to-house system of transformation to service voltage. These circuits were all fed from the Washington street station by means of numerous comparatively small individual generators. The out-lying power load was carried on 500 volt direct current circuits and the series arc business was carried on 6.8 and 9.6 ampere direct current circuits supplied by a number of small individual machines.

While these methods at that time were thoroughly approved and among the best, they now suggest to us visions of barbarity, in view of the tremendous strides in advance since made along the lines of centralization of power generation and uniformity of generating machinery and output, only made possible by the great and rapid development of the modern scheme of distribution through the medium of rotary converter, motor generator and storage battery sub-stations, or a combination of all of them.

At this stage ('97) of the development of electrical distributing systems in Chicago and elsewhere, owing to the rapidly increasing demands for service in the outskirts of an ever extending territory, it became a matter of great urgency to devise and perfect a reliable, effective and efficient link in the distributing system which would bridge the gap between the large central stations and the outlying territory beyond their then economical range of distribution, and at the same time readily adapt itself to the existing conditions without involving duplication of investment or heavy depreciation of the existing system.

Among the first to solve this problem were the engineers of the Chicago Edison Company, who early in 1897 introduced in Chicago the scheme of high tension three-phase alternating transmission from the central generating station to the distant sub-station, and at the latter by means of static transformers and rotary converters, to transform the high tension three-phase alternating current into 230-115 volt direct current to be fed into the local low tension three-wire net work of mains through comparatively short and efficient low tension feeders.

The first transmission of this kind in Chicago was from the Harrison street station to the 27th street station of the Chicago Edison Company, a distance of about three miles. At the Harrison street station a 250 K. W. double current generator was put in operation as an inverted rotary converter receiving 250 volts direct current from the existing D. C. bus bars in the station, and delivering three-phase alternating current under a pressure of about 160 volts. This low tension polyphase alternating current was stepped up to 4,500 volts by means of static transformers, and transmitted at that voltage to the 27th street station about three miles distant, where it was stepped down through a bank of three 80 K. W. static transformers to about 75 volts three-phase and fed into the A. C. end of 2-100 K. W. rotary converters, which delivered 125 volts direct current to each side of the existing three-wire station bus bars and thence distributed to the surrounding net work of mains through existing three wire feeders.

The next step in the development of this system of transmission and conversion included the changing over of one of the three-wire direct current units to a set of two combination alternating current and direct current generators at Harrison street station and the installation of two 200 K. W. rotary converters at the 27th street station. The unit at Harrison street consisted of a 600 H. P. Southwark triple expansion condensing engine direct connected to 2-200 K. W., 150 volt D. C. General Electric generators. These machines were substituted for practically identical ones having taps taken off the armature winding 120 electrical degrees apart, with corresponding taps paralleled, and the three sets led to three collector rings on each machine. This unit then delivered its full load capacity in either direct current or three-phase alternating current or any combination of either at the same time. Additional static transformers were provided and the low tension alternating current stepped up to 4500 volts and regularly operated in parallel with each other, and with the inverted rotary converter already mentioned.

From this time forward the rotary converter sub-station system has developed very rapidly and another 600 H. P. equipment has been converted to a combination unit, a new combination unit has been installed consisting of a 3500 H. P. Reynolds-Corliss compound condensing engine direct connected to a 2500 K. W. double current generator delivering either direct current at 300 volts or six phase alternating current at approximately 180 volts, or any combination of either up to its full capacity; and a new Reynolds-Corliss compound condensing engine direct connected to a 3500 K. W. 9000 volt, three-phase 25 cycle General Electric generator, and two temporary rope driven 1000 K. W. 9000 volt three-phase 25 cycle General Electric generators have been provided at the Harrison street station to meet the demands for current by the fifteen sub-stations and semi-sub-stations now fed by that station and scattered throughout the city.

During the past year the transmission system has been changed from 4,500 to 9,000 volts, by changing the primaries of all the old transformers from a parallel to a series connection. All rotary-converter and motor-generator sub-stations are, at the present time, fed by the Harrison street station, the ultimate capacity of which has been reached, and a 100,000 H. P. high tension polyphase alternating current generating station is now under construction to meet the heavy prospective increase in load to be distributed through sub-stations. Fifty-seven per cent of the load carried by the Harrison street station last December, during the annual

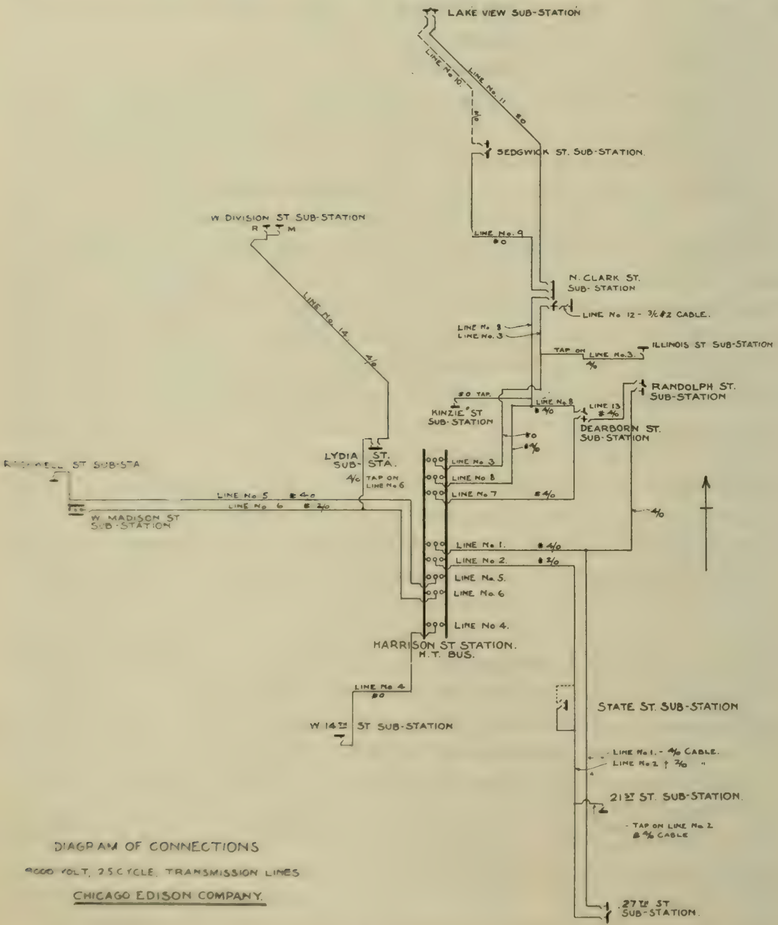


Figure 1.

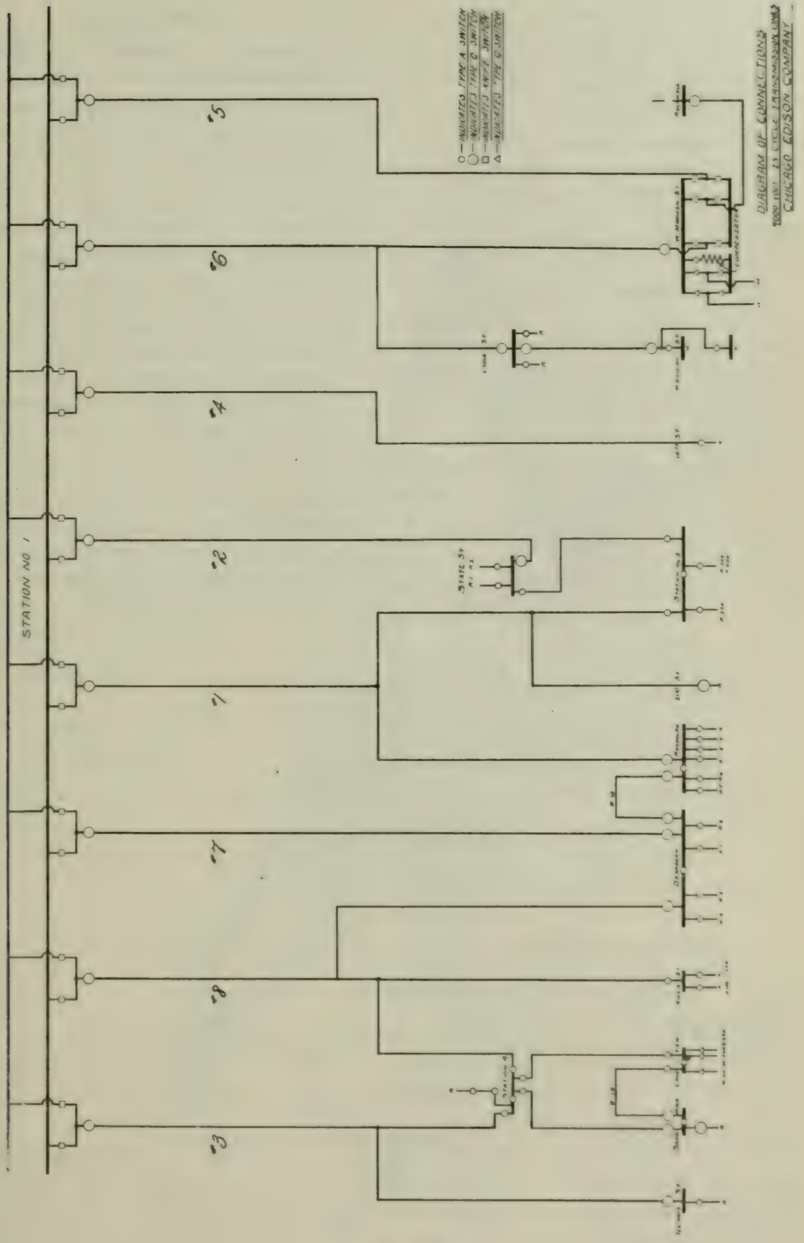
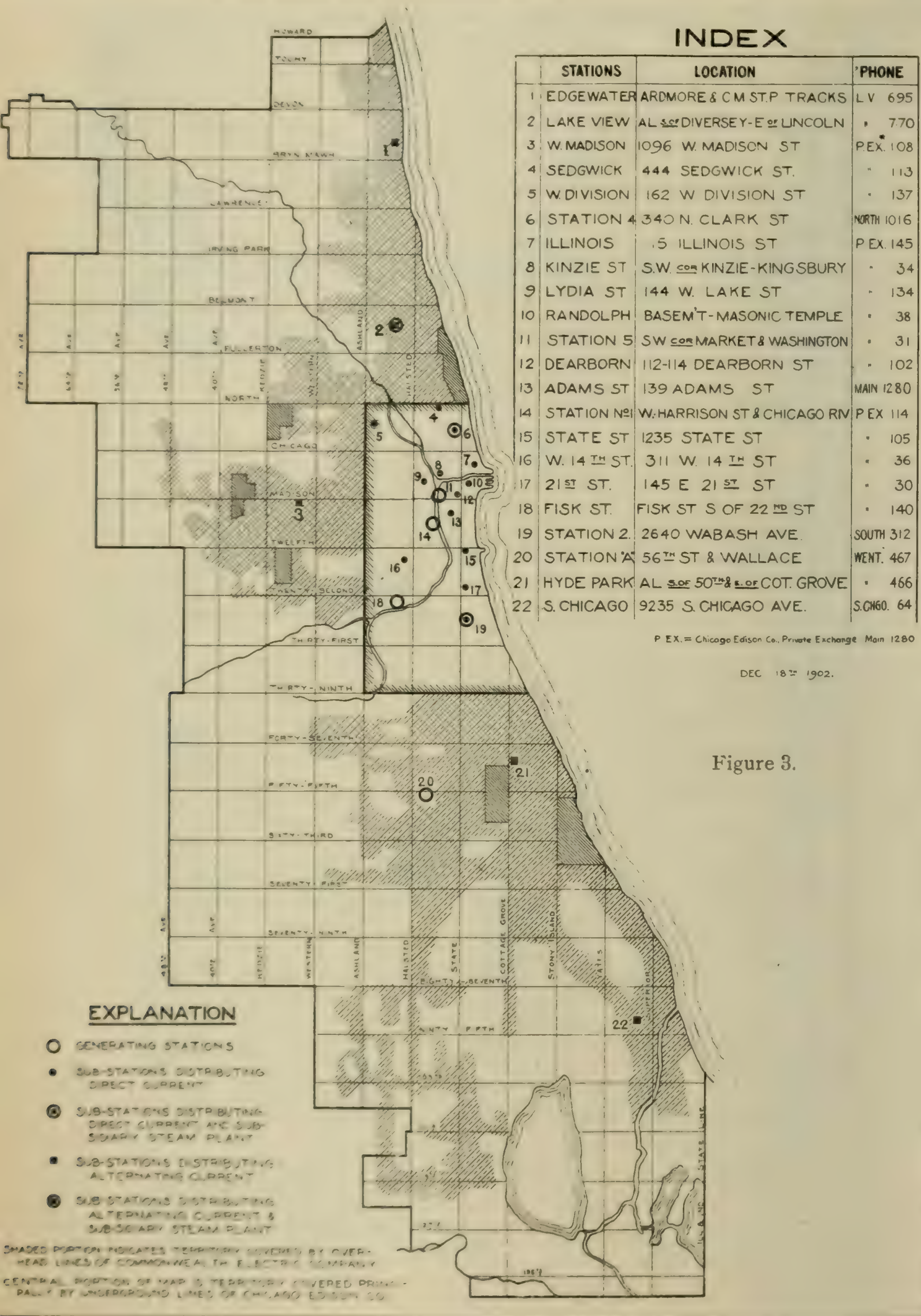

STATION NO 1
5
6
4
2
1
7
8
3
○—INDICATES TYPE A SWITCH
◯—INDICATES TYPE C SWITCH
□—INDICATES KNIFE SWITCH
△—INDICATES TYPE G SWITCH
DIAGRAM OF CONNECTIONS
9000 VOLT 25 CYCLE TRANSMISSION LINES
CHICAGO EDISON COMPANY
W MADISON ST
COMPENSATOR
STATE ST
STATION No 2
DEARBORN
STATION 4

Figure 2.



INDEX

	STATIONS	LOCATION	'PHONE
1	EDGEWATER	ARDMORE & C M ST.P TRACKS	L V 695
2	LAKE VIEW	AL S.OF DIVERSEY-E OF LINCOLN	" 770
3	W. MADISON	1096 W. MADISON ST	P.EX. 108
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5	W. DIVISION	162 W DIVISION ST	" 137
6	STATION 4	340 N. CLARK ST	NORTH 1016
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8	KINZIE ST	S.W. COR KINZIE-KINGSBURY	" 34
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11	STATION 5	SW COR MARKET & WASHINGTON	" 31
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14	STATION Nº1	W. HARRISON ST & CHICAGO RIV	P EX 114
15	STATE ST	1235 STATE ST	" 105
16	W. 14TH ST.	311 W. 14TH ST	" 36
17	21ST ST.	145 E 21ST ST	" 30
18	FISK ST.	FISK ST S OF 22ND ST	" 140
19	STATION 2.	2640 WABASH AVE.	SOUTH 312
20	STATION 'A'	56TH ST & WALLACE	WENT. 467
21	HYDE PARK	AL S.OF 50TH & E.OF COT. GROVE	" 466
22	S. CHICAGO	9235 S. CHICAGO AVE.	S.CHGO. 64

P. EX. = Chicago Edison Co., Private Exchange Main 1280

DEC 18TH 1902.

EXPLANATION

○ GENERATING STATIONS

• SUB-STATIONS DISTRIBUTING DIRECT CURRENT

◉ SUB-STATIONS DISTRIBUTING DIRECT CURRENT AND SUBSIDIARY STEAM PLANT

■ SUB-STATIONS DISTRIBUTING ALTERNATING CURRENT

● SUB-STATIONS DISTRIBUTING ALTERNATING CURRENT & SUBSIDIARY STEAM PLANT

SHADED PORTION INDICATES TERRITORY COVERED BY OVERHEAD LINES OF COMMONWEALTH ELECTRIC COMPANY

CENTRAL PORTION OF MAP IS TERRITORY COVERED PRINCIPALLY BY UNDERGROUND LINES OF CHICAGO EDISON CO.

Figure 3.

maximum period, was transmitted to sub-stations for conversion and local distribution, and the remaining 43 per cent was distributed direct from the station bus bars through the mammoth 66,000,000 c. m. low tension trunk line running to the Adams street sub-station (a storage battery sub-station and center of distribution at 139 Adams street), and through low tension three-wire feeders running into the territory adjacent to the station. This 9,000-volt, 25-cycle, three-phase load was transmitted to fifteen sub-stations and semi-sub-stations, over eight three-conductor paper insulated lead-covered transmission lines, ranging in size from No. 0 to No. 4–0. B. & S., in length from one to five miles, and in capacity up to 3,000 K. W. each.

Figures 1 and 2 are diagramatic representations of the connections of these transmission lines, from which it will be observed that practically every sub-station is fed by a duplicate transmission line directly or indirectly from the generating station, thus affording security against a shut-down in the event of trouble on one of the lines. These duplicate lines have been, as far as practicable, carried over different routes and through different conduit systems as additional security against interruption to the service. In all manholes the transmission lines are wrapped with asbestos and brass tape to protect them from the spreading of burn-outs on other circuits in the same manhole or from gas explosions therein. Each transmission line is provided with three single pole double-knife-blade double-throw transfer switches at the power house for the purpose of transferring lines from one to the other of two sets of high tension bus bars, also an automatic remote controlled cellular brick compartment oil break switch at both the station and sub-station ends, equipped with overload coils which act to open the switch and break the arc in oil in case of short circuit or excessive overload. For well known reasons no live transmission line or high tension circuit is ever opened except in oil.

The locations of the fifteen sub-stations and semi-sub-stations fed from the Harrison street station are shown in Figure 3 as numbers 2 to 10 inclusive and 12, 15, 16, 17, 19 and 22. This figure is largely self-explanatory, indicating as it does the nature of the output, the service furnished by each sub-station and the territory covered by the same. The generating plant indicated by No. 20 is a modern 4150-2400 volt three-phase 60-cycle compound condensing plant equipped with star connected generators with the neutral or common, fourth wire, brought out. Single-phase circuits are carried from the outside phase wires and the common wire leading to the center of the star, and three-phase four wire circuits are operated for combined lighting and power service. The substation indicated by Figure 21 is connected with this power house by means of 2 four-wire 4150-2400 volt transmission lines and serves largely as an alternating single phase distributing center. The sub-stations receiving 9,000 volt current from the Harrison street station range in capacity at the present time from 200 K. W. to 3,000 K. W., with provisions made for extension up to 6,000 K. W. in the case of Randolph street sub-station shown as No. 10 in Figure 3. These figures do not include capacity of the large storage batteries in many of the sub-stations. Rotary converters in service at the present time range in capacity from 100 K. W. to 1,000 K. W., the latter being in a 500 volt elevated railway station. Motor generators range in capacity from 250 to 500 K. W. and storage batteries range from 1,060 amperes to 11,200 amperes at the one-hour rate. The motor generators referred to consist of 9,000 volt, 25 cycle three-phase synchronous motors direct connected to 4150-2400 volt star wound four-wire 60-cycle three-phase generators. These motor-generators are arranged to operate in parallel on both the 25 and the 60 cycle ends. The generators supply single-phase lighting and three-phase power service as well as a combination of both, the latter, from a single four-wire circuit as described in the case of distribution from generating station No. 20, Figure No. 3. The older small rotary converters are three-phase, but all of the modern larger machines are six-phase owing to the advantages possessed by six-phase over three-phase in the way of comparative investment, efficiency and smaller size for a given output, thus permitting the use of much larger machines in basements in the down-town districts where the head room is always limited.

The capacity of rotary converters installed in the down-town district has thus far been limited to 500 K. W. each, on account of this consideration of limited head room. The largest battery installation in a single sub-station is that of Adams street, No. 13, Figure 3, where we have three batteries each of a capacity of 11,200 amperes or a total of 33,600 amperes at the one hour rate based upon minimum voltage of approximately 130 volts on each leg of the battery at the termination of discharge, or about 1.7 volts per cell. The standard storage battery installation in our sub-stations at the present time comprises 150 cells tapped in the middle of the series to form the neutral point leaving a maximum of 75 cells for each side of the three-wire system. Of this series of 75 cells, from 25 to 30 cells at the end of each series are so connected as to serve as end cells for the purpose of regulation of charge and discharge rates. The terminals of each of these end cells are tapped and lead to the segments of traveling end cell switches separated from the battery room by a fume-tight wall. The traveling brushes of the end cell switches in moving from one segment to the next adjacent one makes connection from the segments to common bus bars which are connected to the distribution bus bars of the sub-station, and thus includes or excludes one cell at a time, thereby raising or lowering the output of the battery. The movement of the traveling brushes is effected by a direct connected direct current motor which is controlled from the main operating switchboard of the sub-station. From two to three sets of these end cell switches connected in parallel are usually provided in order to permit of the battery being discharged on as many sets of bus bars carrying as many different voltages, or to charge and discharge at the same time if desirable, or to operate all of the switches in parallel on the same set of buses if the rate of discharge requires their combined capacity.

The storage batteries are charged late at night when the load on the generating station is light, and discharged late in the afternoon during the peak of the load, thus largely improving the station load factor, and so long as the width of the peak does not exceed about two hours, saves necessary investment as compared with steam generating equipment. Quite frequently during the maximum period of the year, in sub-stations having both rotary converters and storage batteries operating in parallel on the same sub-station bus bars, the battery during the peak is allowed to carry the entire load of the sub-station and, by inverting the rotary converter, to feed back into the 9,000-volt three-phase transmission system, and thus relieve the central generating station to the full extent of the capacity of the storage batteries. The aggregate capacity of the storage batteries at the one hour rate amounts to 63,480 amperes, that of the motor generators to 2250 K. W., and that of the rotary converters to 11,700 K. W. at the present time.

The general scheme of conversion from 9,000 volt three-phase 25-cycle current to 250-125 volt three-wire direct current in our rotary sub-stations at the present time is as follows: 9,000 volt three-phase 25-cycle current enters the sub-station through three conductor-stranded-copper, paper-insulated, lead-covered, 4-0 (usually) cable, and passes through cellular brick compartment oil switches into the 9,000 volt buses of the sub-station. By means of tie switches any one of these lines can be so connected as to carry the entire sub-station load or any part of it, or all of the lines can be operated in parallel on the same load.

From the 9,000 volt three-phase bus bars the current is lead through three-conductor cable laid in trenches beneath the floor, to a single throw quick acting oil switch located near the bank of three step-down transformers which deliver six-phase current at about 170 volts to the alternating end of the rotary converter through an induction regulator. The direct current delivered by the rotary is carried through a circuit breaker mounted on the frame of the machine and thence through double throw switches on the low tension switchboard. These switches throw to either the main or the auxiliary bus bars or both, thus providing means of operating a high or low bus if desirable in sub-stations having more than one machine. The machine bus bars are mere extensions of the feeder buses. No fuses or safety catches are employed except in rotary starting circuits and in primaries of the small potential transformers.

For partial protection while starting and synchronizing a rotary, this starting fuse is left in circuit across the open positive main switches, which are not closed until after the machine has been cut in parallel with the alternating system. Protection against overloads or short circuits on the 9000 volt leads is provided by means of series transformers in circuit with these leads, the secondaries of which act upon solenoids having cores which when drawn up into the coils close a low tension direct current circuit through the main opening solenoids of the high tension oil switches already referred to. These latter solenoids open the switch through the medium of a steel strap bolted to a shaft equipped with a crank and connecting rod which acts directly on the mechanical mechanism of the switch. This same action, or that of opening the switch, is under control by the operator at the main operating switchboard by means of a small double throw control switch with which current may be sent through either the opening or closing main solenoids of the main oil switches. The circuit breaker in the D. C. leads from the rotaries are not affected by overloads but are actuated only by reverse current and speed limit devices. The speed limit device consists of a small lever attached to the end of the converter shaft in such a manner as to fly out under the action of centrifugal force and close the circuit through the tripping coil of the direct current curcuit breaker when the speed exceeds a pre-determined safe limit. Reverse current acts upon the breaker in the following manner: The indicating needle of the main direct current ammeter of the converter, in the case of reverse current, drops back against a stop in the meter and closes the circuit through the tripping coil of the circuit breaker. In case of short circuits or grounds on the high tension lines or at the power house, this device proves very effective in preventing the rotary from inverting and drawing current from the direct current network and feeding back into the high tension trouble.

The converters are started up from the direct current bus bars which are always alive by back feed from the main network. The rotary is thus brought up to synchronous speed as a simple direct current motor with the three pole oil switch between the high tension side of the transformers and the 9000 volt bus bars OPEN.

When the machine is in step with the alternating buses as indicated by a Lincoln synchronizer, the above mentioned 9000 volt switch is instantly closed by closing the small control switch on the main switchboard, after which the main D. C. converter switches are closed and the load picked up by boosting the low tension six-phase alternating current voltages by means of an induction regulator in circuit between low tension side of the transformers and the alternating current end of the rotary; this regulator being also electrically controlled from the main switchboard.

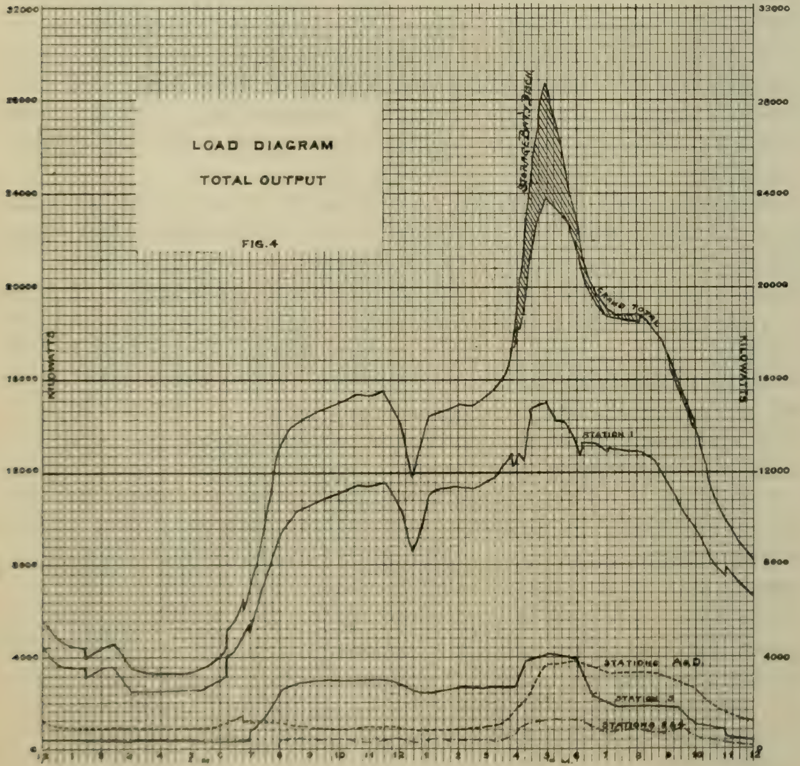
In some of the older installations, synchronizing is effected by the use of incandescent lamps connected in series with the low tension alternating current leads of the rotary, and by closing manually operated switches in these leads when the lamps are dark and beating slowly. All direct current ammeter shunts are provided by tapping the main current carrying leads, and connecting in series with the ammeter leads compensating coils made up of fine wire wrapped around the main leads to compensate for varying temperatures under varying loads.

The motor generator sets are started up as Hysteresis motors from compensators delivering three-phase current at approximately 4500 volts. The main 9000 volt leads from the motor connect to the center points of a three pole double throw oil switch controlled from the operating board, which connects the motor to either the 9000 volt buses direct, or to a compensator which is receiving current therefrom.

In starting, the field circuit of the motor is left open and the main switch thrown to the compensator bus carrying 4500 volts. When the machine has attained full speed the switch is thrown to the 9000 volt bus and the field circuit closed. The motor is then operating as a three-phase synchronous motor and the field current is adjusted for unit power factor, after which the generator field circuit is closed, the voltage adjusted and the generator cut in on the load in the ordinary manner.

In synchronizing these generators, since they are driven by synchronous motors each with the same number of poles operating on the same set of bus bars, and there are five pairs of poles on the motors and twelve pairs on the generators, there is only one chance in five that the incoming generator will be in electrical synchronism with those with which it is to be paralleled. A double Lincoln synchronizer is employed in paralleling these machines, the instrument consisting essentially of two independent single synchronizers mounted in one case, each of whose hands travels independently over the same dial. When the incoming motor has attained synchronous speed its sychronizer hand will take up a vertical position marked zero, indicating perfect synchronism with regard to the motors. The generator synchronizing hand, however, will remain constantly at one of five angular positions having corresponding figures marked upon the dial showing the number of pairs of poles which the incoming motor must be caused to slip in order to bring the generators into step. This slipping is accomplished in the following manner: With the fields of the incoming motor excited (in order to generate pressure by the momentum of the machine for the operation of the motor synchronizer) the three pole oil switch in its main 9000 volt leads is opened and the motor synchronizer hand immediately begins to rotate as the motor loses speed. When its hand has made as many revolutions as the number of pairs of poles to be slipped, the main 9000 volt motor switch already referred to is instantly closed while the synchronizing hand is passing zero on the dial, or at the instant when the motors are in perfect step.

As soon as this is accomplished both hands will occupy the vertical position indicating perfect synchronism with no displacement excepting that produced by the drag of the loaded motor. The pressure on the incoming generator is then adjusted and the gen-


LOAD DIAGRAM

TOTAL OUTPUT

FIG. 4

erator thrown in parallel with those already operating. All of the main switches used in connection with these machines are controlled by means of small control switches on the main switchboard which act upon solenoids or small motors, which in turn actuate the mechanisms of the large switches.

I believe the Lincoln synchronizer is now so well known as to require no description here. It is needless to say that synchronizing switches and buses are provided, which permit the use of the same double synchronizer for all machines. This also applies to all of the rotary sub-stations.

One of the heaviest local three-wire low-tension loads supplied by a sub-station is that of Marshall Field's retail store, having an equivalent connected load of approximately 75,000 16 c. p. lamps requiring 19 services. By way of illustration of the rapid advances made along the lines of sub-station distribution, it may be of interest to note that during the past year the output of stations has increased approximately 76 per cent; while the increase in sub-station oper-

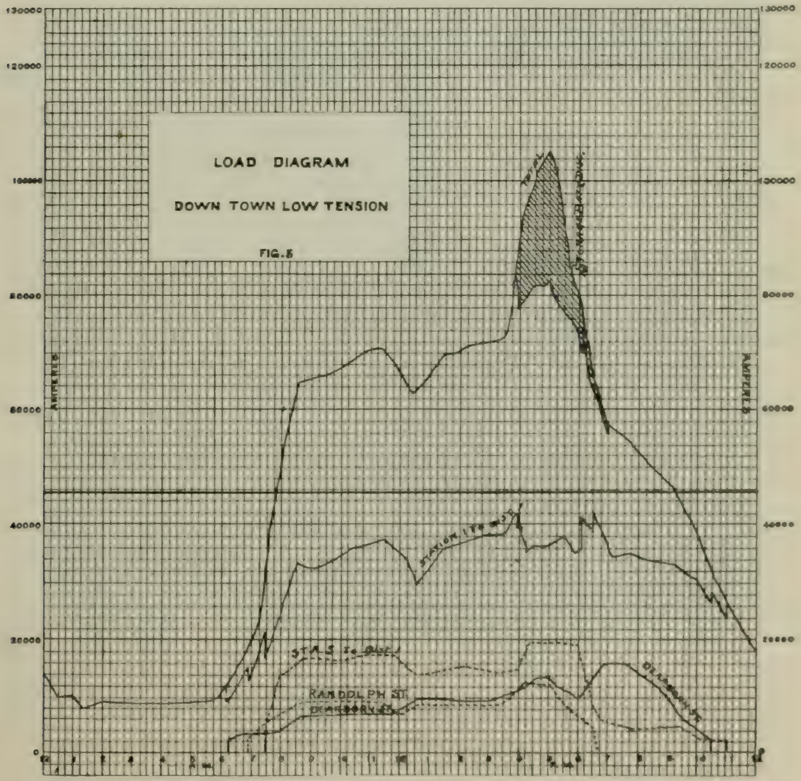
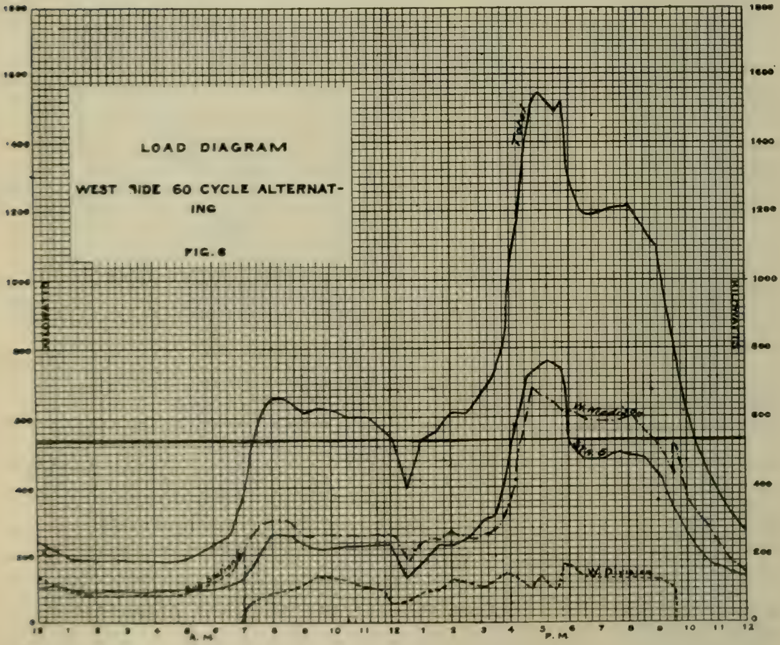


FIG. 8

ating hours has been approximately 23 per cent; the increase in number of sub-stations in operation about 83 per cent, and the increase in the number of storage battery installations about 167 per cent. Figures 4, 5, and 6 are typical load curves showing the characteristic features of the load during the maximum period of the year; the continued battery discharge at low rate between the hours of 6:00 and 8:00 p. m., figure 4, represents the output of auxiliary high buses for the purpose of maintaining the pressure at the ends of long feeders. The other curves are largely self-explanatory.

Owing to limited space, I have necessarily treated the subject of this article only in a very general manner, omitting many interesting diagrams and much interesting detail.



CLXXI.

GROUNDING OF ALTERNATE CURRENT SYSTEMS.

By Geo. N. Eastman.

Read before the Chicago Electrical Association, April 3, 1903.

On any alternating current system which is well insulated from earth, the relative pressure which exists between any part of the system and the ground, normally depends upon the distribution of electro static capacity throughout the system. Any change which takes place in the distribution of condensance produces a relative change in the earth potentials. Shunting the condensance of any part of the system with an ohmic resistance or inductive reactance will also produce a change in earth potentials. It is the object of this paper to show the effects produced when the latter conditions are obtained and present a few problems with diagrams showing conditions which will arise and produce very disastrous results.

In January of last year Mr. Nies gave a talk before the Chicago Electrical Association on the subject of "Grounding of High Potential Systems." He pointed out that leaving the effects of static capacity out of consideration, a system not grounded was entirely free from difference of potential relative to the earth, and could be grounded with impunity through the human body. He presented a method of treating the subject which was entirely original, and developed formula by the use of which it was made possible to determine the relative pressures which would exist between any conductors and ground, when one conductor of a system was grounded through an ohmic resistance. With the assistance of Mr. Nies the formulæ given in this paper have been developed for determining the relative ground potentials when electro static capacities are not balanced on the system, and when one conductor of the system is grounded through an inductive reactance.

The electro static capacity of any system is always shunted by the insulation resistance. The value of insulation resistance, however, is so much greater than the reactance of condensance, that it can be entirely disregarded. The following examples show the relation of these values.

The insulation resistance of a circuit one mile in length consisting of two 4-0 conductors placed 12 inches apart in the air, would normally exceed 500 meg. ohms. The reactance of condensance between these two conductors with 60 cycles would be 159,800 ohms. The insulation resistance of a 10,000 volt 4-0 paper-insulated, lead-covered cable should exceed 500 meg. ohms per mile. The reactance between one conductor and lead of this cable will be approximately 14,000 ohms.

Throughout this paper a four-wire, three-phase system has been considered. Relative conditions will arise on any A. C. system and the conclusions drawn from the problems presented will hold equally well for any system.

Before presenting the problems, in order to give a clearer idea of their value it is advisable to show the distribution of condensance in a three-conductor cable and give the values of condensance and reactance for the three-phase systems operated by the Chicago Edison Co. and the Commonwealth Electric Co.

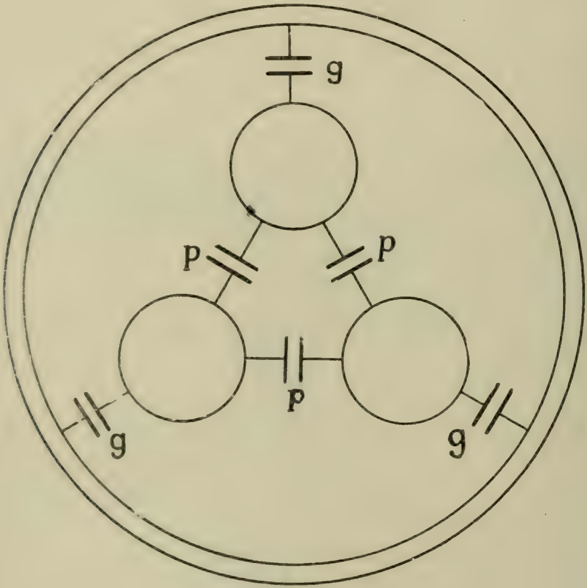


Fig. 1

Fig. 1 represents the distribution of condensance in a three-conductor, lead-covered cable. It can be readily seen from the figure that in measuring the condensance between conductors or between conductors and lead a value is not obtained representing the true condensance between these two surfaces which can be used in calculating the charging current of the system. The derivation of a formula for obtaining the true condensance is given below. The value obtained in measurement made between conductor and ground and between conductors is represented by Cg and Cp. The value of condensance which can be used in making three-phase calculations are represented by g and p.

From Fig. 1.

$$Cg = g + \frac{1}{\frac{1}{p} + \frac{1}{g}} + \frac{1}{\frac{1}{p} + \frac{1}{g}} = \frac{3pg + g^2}{p + g} \qquad (1)$$

$$Cp = p + \frac{1}{\frac{2}{p}} + \frac{1}{\frac{2}{g}} = \frac{3p + g}{2} \qquad (2)$$

Equating (1) and (2)

$$g = \frac{Cp\,Cg}{3\,Cp - Cg} \qquad (3)$$

$$p = \frac{2\,C^2p - Cp\,Cg}{3\,Cp - Cg} \qquad (4)$$

The 9,000-volt, three-phase, twenty-five cycle distribution system of the Chicago Edison Co. consists of a generating system supplying energy to rotary converter and motor generators sub-stations. The 9,000-volt transmission lines now in operation have a total of 28.88 miles of three-conductor paper-insulated, lead-covered cable varying in size from 1-0 to 4-0. The total condensance between one conductor and lead (represented in Fig. 1 as g) is 5.24 MF. The total reactance of condensance between two conductors with 25 cycles is 3,900 ohms. The total reactance of condensance between one conductor and ground is 1,260 ohms. The charging current per line three-phase at 9,000 volts is 8.11 amperes with 25 cycles. The total charging energy required is 126.3 apparent kilowatts.

The diagrams which will follow pertain to the three-phase, four-wire, sixty-cycle system in the Southern District of the Commonwealth Electric Co. The system operates at a star pressure of 2,300 volts. Values for condensance given were taken for the system in October, 1901. The condensance of the lead cable used throughout the system was measured. The condensance of the overhead lines was calculated, it not being possible to obtain direct measurements. Assuming that circuits were evenly balanced between the phases, total length of the overhead conductor on each phase is 64 miles. The total length of underground conductors is 2.87 miles. The total length of underground neutral conductor is 5.95 miles. The total length of overhead neutral conductor is 157 miles. The total condensance between any two-phase conductors is 2.21 MF and the reactance of condensance between any two-phase conductor is 1,700 ohms. The total condensance between each phase conductor and neutral is 4.3 MF. The reactance of condensance is 900 ohms. The total charging current three-phase per line would be 7.05 amperes. The total energy required for charging the system would be 28 apparent K. W.

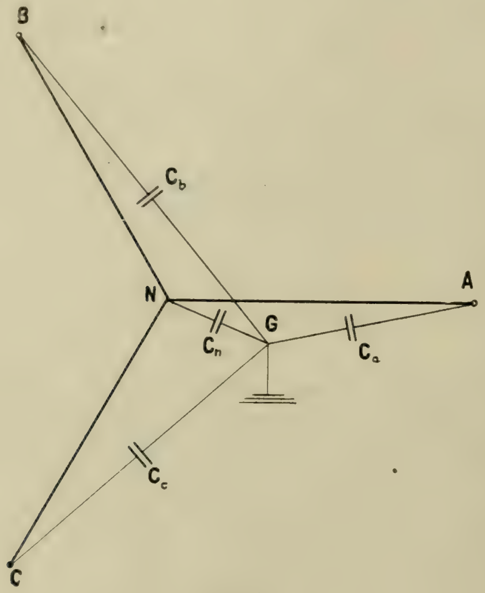


Fig. 2.

This system can be represented by Fig. 2, A, B, C, N representing the star diagram of pressures. Condensers are connected in as shown; Ca, Cb, Cc representing the condensers on the phase conductors and Cn representing the condensance of the neutral conductor. It is evident when the condensance is balanced Ca = Cb = Cc and the voltage impressed on each condenser will be the same. There will be no difference of potential between the neutral of the system and the ground.

Fig. 3 represents a condition which is apt to arise when one-phase conductor is grounded through an ohmic resistance. It is evident that this will change the relative ground potentials of the system. Substituting values for the reactance of condensance, the equation giving the potential between neutral and ground can be derived as follows:

In Fig. 3 let Ca, Cb, Cc, and Cn represent the reactances of Ca, Cb, Cc and Cn, respectively, and r represent the resistance of r.

Let Ia, Ib, Ic and In represent the current which will flow through the condenser Ca, Cb, Cc and Cn, respectively, and Ir the current which will flow through the resistance r.

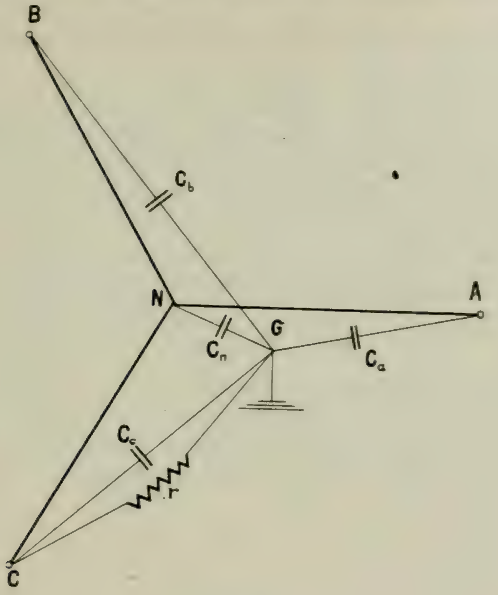


Fig. 3.

Since the sum of all the currents meeting at a mesh point is 0, then

$$Ia + Ib + Ic + In + Ir = O \tag{5}$$

From Fig. 3
$$Ia = \frac{G\,A}{j\,Ca} = \frac{G\,N + N\,A}{j\,Ca} \tag{6}$$

$$Ib = \frac{G\,B}{j\,Cb} = \frac{G\,N + N\,B}{j\,Cb} \tag{7}$$

$$Ic = \frac{G\,C}{j\,Cc} = \frac{G\,N + N\,C}{j\,Cc} \tag{8}$$

$$In = \frac{G\,N}{j\,Cn} \tag{9}$$

$$Ir = \frac{G\,C}{r} = \frac{G\,N + N\,C}{r} \tag{10}$$

Substituting current values in (5) and solving, when star pressure = 2300 volts.

$$N\,G = \frac{r\,Cn\,[2300\,Cb\,Cc - 1150\,Ca\,Cb - 1150\,Ca\,Cc] + 1992\,Ca\,Cb\,Cc\,Cn - j\,Cn\,[1150\,Ca\,Cb\,Cc + r\,(1992\,Ca\,Cb - 1992\,Ca\,Cc)]}{r\,Cn\,Cb\,Cc + Cn\,Ca\,Cb + Cn\,Ca\,Cc + Ca\,Cb\,Cc + j\,Cn\,Ca\,Cb\,Cc}$$

When $Ca = Cb = Cc$ (11)

$$\text{then } N\,G = \frac{1992 - j\,1150}{r\left(\frac{3}{Cc} + \frac{1}{Cn}\right) + j\,1} \tag{12}$$

From equation 12 an expression can be obtained for the tangent of the angle A N G. It is easier to substitute numerical values in equation 12 and lay the angle off graphically, than to solve for the tangent of the angle.

In equation 12, taking for the values of Ca, Cb, Cc and Cn, the value of reactance of the condensance in the case cited above, "The Southern District of the Commonwealth Electric Co.", the pressures to ground have been determined for values of r, varying from infinity to 0.

When r = inf. NG = 0 AG = 2300 BG = 2300 CG = 2300
When r = 2000 NG_1 = 394 AG_1 = 2020 BG_1 = 2675 CG_1 = 2265
When r = 500 NG_2 = 1315 AG_2 = 2115 BG_2 = 3610 CG_2 = 1885
When r = 125 NG_3 = 2165 AG_3 = 3450 BG_3 = 4190 CG_3 = 755
When r = 0 NG = 2300 AG = 3980 BG = 3980 CG = 0

Diagram Fig. 4 represents these conditions. It can be seen from this that with the balanced conditions of electro static capacity, one condenser being shunted by an ohmic resistance, it is possible to obtain potentials greater than the delta pressure of the system.

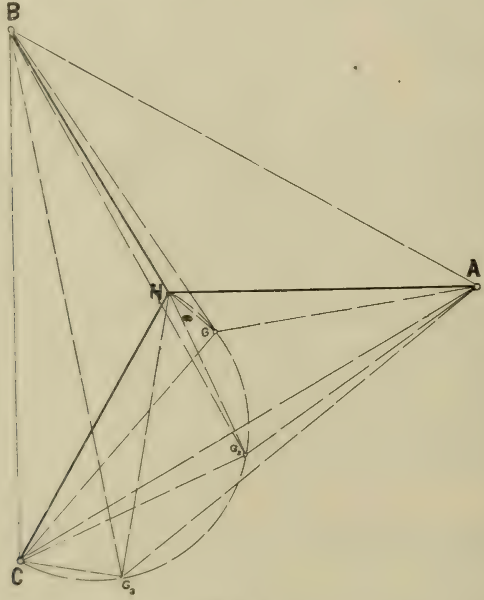


Fig. 4.

Referring to Fig. 2 it can readily be seen that if the electro static capacities are not balanced on each phase the neutral will not operate at the ground potential. Taking the condition where the total electro static capacity of the system is the same as in the example previously cited but considering that an unbalance has taken place, such that Ca = 1150 ohms, Cb = 2270 ohms, Cc = 2270 ohms and Cn = 900 ohms, and assuming the same values of r as in the previous example, then substituting these values in equation 11 the relative pressures to ground given in the table below are obtained.

When r = inf, $NG = 345$, $AG = 1955$, $BG = 2395$, $CG = 2495$.
When $r = 2000$, $NG_3 = 710$, $AG_3 = 1690$, $BG_3 = 2915$, $CG_3 = 2460$.
When $r = 500$, $NG_5 = 1570$, $AG_5 = 2030$, $BG_5 = 3870$, $CG_5 = 2050$.
When $r = 0$, $NG = 2300$, $AG = 3980$, $BG = 3980$, $CG = 0$.

Diagram Fig. 5 represents these conditions and in connection with the table given shows that with the unbalanced electro static capacity, pressures to ground will exceed the pressures obtained on a system having balanced electro static capacity.

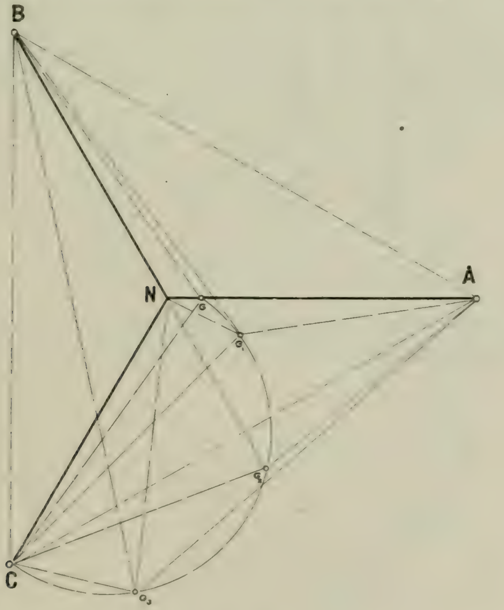


Fig. 5.

In the preceding examples it has been considered that the phase condenser was shunted by an ohmic resistance.

Diagram 6 shows a condition which may be obtained where the ground is of an inductive character. N, A, B and C represent the bus bars of a four-wire, three-phase system. One circuit is shown connected to the bus bars N and A. The capacity of the neutral of this circuit is represented by the condenser Cd. The capacity of the rest of the system is represented as Cn, Ca, Cb and Cc. In a case where the neutral fuse blows and the fuse on phase wire remains intact, a circuit is completed from bus bar A through the phase wire of the circuit, through the primary of transformer T and through the condenser Cd, to ground. In case the neutral had

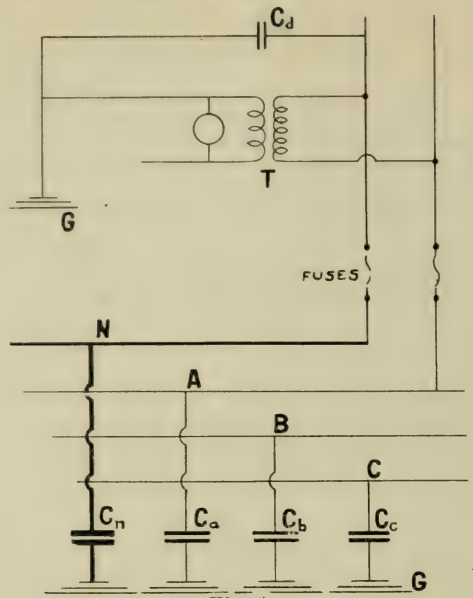


Fig. 6.

become grounded, short circuiting the condenser Cd, the ground would have been obtained through the primary of the transformer only.

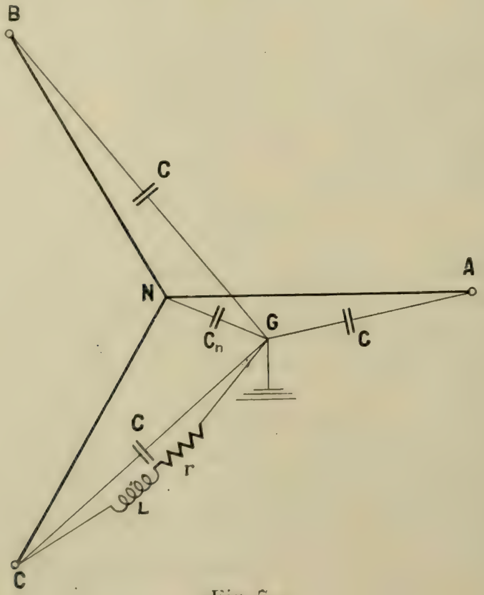


Fig. 7.

Fig. 7 represents the condition when a phase wire is grounded through an ohmic resistance in series with an inductive reactance. It is evident that ohmic resistance will always shunt the inductive reactance instead of being connected in series with it as shown. The series condition was chosen on account of its simplicity.

The following is the derivation of the formula for obtaining the pressure from neutral to ground for any values of L and r. The condensance on the system is assumed to be balanced and the reactance of each phase condenser is represented by x. The reactance of the neutral condenser is represented by y. The ohmic resistance is represented by r and the inductive reactance of L is represented by w.

Let Ia represent the current in A phase-condenser, Ib the current in B phase-condenser, Ic the current in C phase-condenser, In the current in the condenser Cn, and Ir the current in rl.

$$Ia = \frac{GA}{j\,x} = \frac{GN + NA}{j\,x} \tag{13}$$

$$Ib = \frac{GB}{j\,x} = \frac{GN + NB}{j\,x} \tag{14}$$

$$Ic = \frac{GC}{j\,x} = \frac{GN + NC}{j\,x} \tag{15}$$

$$In = \frac{GN}{j\,y} \tag{16}$$

$$Ix = \frac{GN + NG}{r - j\,w} \tag{17}$$

$$Ia + Ib + Ic + In + Ir = 0 \tag{18}$$

Substituting the current values in I and solving

$$GN = NC \frac{x\,y}{w\,(3y + x) - xy + jr\,(3y + x)} \tag{19}$$

Substituting for GN its vector value, $-a \rightarrow j\,b$ where $a = 1150$ and $b = 1992$

$$GN = \frac{-xy\,(a + j\,b)}{w\,(3y + x) - xy + j\,r\,(3y + x)}. \tag{20}$$

$$\text{and Tan. } ANG = \frac{(b\,w - a\,r)\,(3y + x) - b\,x\,y}{(a\,w + b\,r)\,(3y + x) - a\,x\,y} \tag{21}$$

Substituting in this equation a value of 1,700 ohms for x and a value of 900 ohms for y and assuming the resistance in series with the inductive reactance is 0, when w is equal to infinity, GN is 0, when w has a reactance of 348 ohms, GN is infinity and when w has a reactance of 0 ohms, Gn is 2,300. A study of this condition will show that when the phase wire is grounded through a purely inductive 'reactance, and the reactance is varied from infinity to 0, the pressure from neutral to ground follows the direction of the line NG shown in Fig. 8. With a reactance of 348 ohms the line swings through infinity and as the reactance decreases the voltage travels back on the path of the line NC until GN = CN.

Fixing the value of inductance at 695.5 ohms and varying the value of resistance from 0 to infinity, it is found that the ground potential follows the curve shown in Fig. 8. With r = 0, GN = 2300 volts; with r = 200, GN = 1386 volts; with r = 500, GN = 1085 volts; with r = 1000, GN = 907 volts; and when r = inf. GN = 0. These points are shown in the curve as G_1, G_2 and G_3.

The examples which have been presented all show that when the resistance or reactance grounding any phase conductor bear certain ratios to the condensance reactance of the system, excessively high potentials will be obtained between the system and ground.

Another effect which adds new complications to the problems given may be best illustrated by the actual results obtained from experiment. A conductor as shown in Fig. 9 was connected to a 60-cycle alternator, generating 2,300 volts. One side of the alternator was grounded, the other side being connected to the line through a lamp and the spark gap S. An ammeter was connected in series with the spark gap and lamp and an electro static voltmeter was connected between the line and ground. With the spark gap closed, the charging current taken by the line was 0.125 amperes which corresponds to a reactance of 18,400 ohms. Opening the spark gap 0.05 of an inch the 16 candle power lamp burned steadily above candle power and the ammeter indicated a current flow of

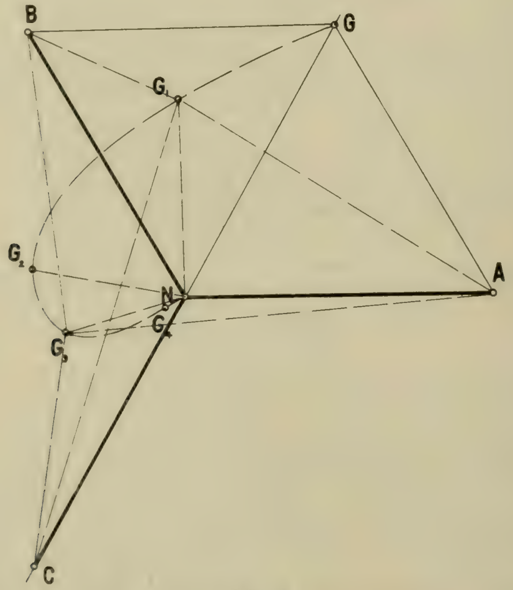


Fig. 8.

0.87 amperes, indicating an increase of practically seven times the original current. The static voltmeter showed no increase in voltage. Apparently the reactance of the condensance dropped from 118,400 ohms to 2,640 ohms. There appears to have been an increase in frequency. This, however, could not be definitely ascertained as there was no means at hand to determine the wave form of the current.

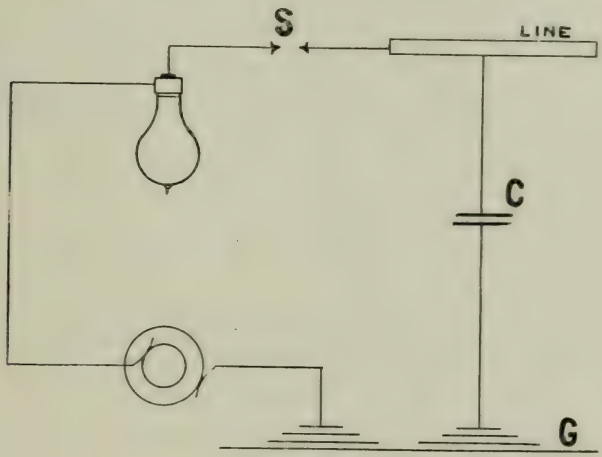


Fig. 9.

Assuming the above conditions were due to an increase in frequency such as a higher harmonic, or combination of harmonics, it will be seen that if the phase wire fuse of the circuit shown in diagram 6, ruptures, the condition shown in this experiment may be obtained. Excessive voltages might then result, due to the change in the ratio of the inductive and condensance reactance included in the circuit.

The conditions considered show conclusively that it is desirable to permanently ground any alternate current system to eliminate the high potentials which otherwise would be obtained between the system and ground.

ABSTRACT OF MINUTES OF THE SOCIETY.

REGULAR MEETING, March 4, 1903.

A regular meeting of the Society (No. 491) was held in the Society Rooms on the evening of Wednesday, March 4th.

The meeting was called to order at 8:20 by President Modjeski, with about sixty members and guests present.

The minutes of the meetings held February 4th and 18th were read and approved.

The Secretary, on behalf of the Board of Direction, announced that at the meeting held Tuesday, March 3d, the following persons were elected members of the W. S. E. under their respective grades:

Fred L. Thompson, Chicago, Active.
Thos. W. Clayton, Chicago, transferred from Junior to Active.
Alfred G. Dupuis, Chicago, Associate.
A. C. Warren, Chicago, transferred from Junior to Active.
Geo. W. Harding, Chicago, Active.
R. B. Mildon, Tercio, Colo., Active.

Also that the following new applications had been received:

Chas. Johnson, New Orleans, transfer from Junior to Active.
H. H. Hadsall, Chicago, transfer from Junior to Active.
Durand Churchill, Chicago, Active.
Max Lee Cunningham, Shawnee, Oklahoma, Junior.
Francis T. West, Chicago, Associate.
Albert H. Westfall, Joliet, Ill., Associate.
William A. Hazard, Des Moines, Iowa, Active.
Arthur Montzheimer, Joliet, Ill., Active.
John P. Ball. Chicago, Active.
Theodore C. Phillips, Brooklyn, N. Y., transfer from Junior to Active.
George E. Ellis, Chicago, Active.
Philip C. Allen, Chicago, Associate.
James L. Young, Bismarck, N. Dak., Active.

The Secretary also reported, by order of the Board of Direction, that a new lease had been signed for the present quarters in the Monadnock Block for the next three years.

On motion of Mr. Finley, duly carried, the report was accepted.

The Secretary also announced, on behalf of the Entertainment Committee, that there would be a public meeting held under the auspices of the Western Society of Engineers and the American Institute of Electrical Engineers, Chicago Chapter, on which occasion Mr. B. J. Arnold, M. W. S. E, would address the company with a resumé of his report to the Chicago City Council on the traction problem of Chicago. The Secretary stated that as there was only a limited edition of Mr. Arnold's report printed, doubtless there were many members of the Society who had not seen it, and thought the matter was of sufficient importance that there should be a full attendance of the members of this Society to hear what Mr. Arnold had to say on this subject. Announcement to be made later of the place and date for holding this meeting.

There being no further business to come before the Society, the President introduced Prof D. C. Jackson, of Madison, Wis., who read the paper prepared by his brother Mr. Wm. B. Jackson, on "Hydraulic Development as Related to Electrical Installations," on account of the latter being unable to be present.

Following the presentation of the paper, written discussion was read by the Secretary prepared by Mr. T. T. Johnston, M. W. S. E. Mr. Mead also presented a written discussion of the subject,

Following this there was some oral discussion from Messrs. Jackson, Gonzenbach, Mead and Sherman.

The meeting adjourned at 9:45 p. m. J. H. WARDER, Secretary,

EXTRA MEETING, March 18, 1903.

An extra meeting (No. 492) was held Wednesday evening, March 18th. It was called to order at 8:15 p. m. by President Modjeski. About seventy-five members and guests were present.

There being no business to come before the Society the President introduced Mr. Ernest Gonzenbach, who presented a paper on "The Third Rail for High Speed Electric Service." The paper was illustrated by many lantern slides. At the conclusion of the presentation of the paper the Secretary read written discussion which had been received from Mr. Geo. E. Thomas, of New York city, and Mr. Paul Winsor, of the Boston Elevated Ry. Co., Boston. There was also some oral discussion from Messrs. Gould, Tratman, Finley, Sturdevant, Modjeski and Carlton.

The meeting adjourned about 10 o'clock. J. H. Warder, Secretary

EXTRA MEETING, March 24, 1903.

An extra meeting (No. 493) was held in Fullerton Hall, Art Institute, Tuesday evening, March 24th, at 8 p. m.

This was a joint meeting of the Western Society of Engineers and the Chicago branch of the American Institute of Electrical Engineers, and was addressed by Mr. B. J. Arnold, M. W. S. E. and A. I. E. E., on "The Chicago Transportation Problem." Invitations had been extended to officials of the City of Chicago, the Street Car Companies, the Gas Companies, the Telephone Companies, and many business men of Chicago.

There were about 400 present who were interested in Mr. Arnold's resumé of his report to the City Council, which was illustrated by many lantern slides.

J. H. Warder, Secretary.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the last issue of the JOURNAL for February, 1903, we have the pleasure to report the following gifts from donors named:

GOVERNMENT PUBLICATIONS.

Library of Congress, Washington, D. C., pamphlet, Bibliography of Coöperative Cataloguing and the Printing of Catalogue Cards. 1850–1902.

U. S. Dept. of the Interior, Commissioner of Education, one book, cloth, Report for year 1900-1.

U. S. Dept. of the Interior, one book, cloth, Report Commissioner of Labor for 1900-1, Vol. 2.

U. S. Dept. of Agriculture, Foreign Markets, various pamphlets,
Experiment Station, one book, cloth, Report Irrigation Investitions, 1901.
Bureau of Forestry, two pamphlets, "The Redwood," "Conservative Lumbering at Sewanee, Tenn."

E. E. R. Tratman, M. W. S. E., pamphlet, U. S. Dept. of Agriculture, "Road Conventions in the Southern States." 1902.

C. W. E. Clarke, M. W. S. E., one book, cloth, "Year Book of the U. S. Dept. of Agriculture for 1901."

E. E. R. Tratman, U. S. Dept. of Agriculture, Public Roads, "Proceedings North Carolina Good Roads Convention, Feb. 1902."
"Proceedings International Good Roads Convention, 1901."
"Proceedings Road Conventions in the Southern States."
"Road Building with Convict Labor in the Southern States."
One book, cloth, "Test of Metals, etc.," 1901, U. S. War Dept.

James R. Mann, M. C., one book, cloth, "Year Book of the Dept. of Agriculture, 1900."

U. S. Commissioner of Labor, one book, cloth, 17th annual report, 1902, "Trade and Technical Education."

James R. Mann, M. C., cloth bound volume, "Abstract of the Twelfth Census of the United States, 1900."

U. S. War Dept., cloth bound volume, "Test of Metals, etc," 1901.

C. H. Tutton, Dept. of Public Works, Buffalo, four pamphlets, Annual Reports, 1897, 1898, 1899, 1900.

Commissioner of Public Roads, State of New Jersey, 9th annual report, 1902.

U. S. Geological Survey, four cloth bound volumes, Parts 1, 2, 3, 4, 22d Annual Report, 1900-1901.

Cincinnati Commissioners of Water Works, cloth bound volume, 6th Annual Report 1902, Board of Trustees.

Department of State Engineer and Surveyor, New York, pamphlet, Proceedings 4th annual Supervisors Highway Convention, 1903.

State Engineer, Colorado, cloth bound volume, 11th Biennial Report, 1901-2.

Lawrence, Mass., Water Board, pamphlet, Annual Report for 1901.

Ohio State Board of Health, one book, cloth, 16th Annual Report, 1901.

C. J. Poetsch, City Engineer, Milwaukee, Wis., pamphlet, Annual Report for 1901.

BOOK NOTES

Ancient and Modern Engineering and the Isthmian Canal. By William H. Burr. C. E. Professor of Civil Engineering in Columbia University M. Am. Soc. C. E.; M. I. C. E. of Gt. B. pp. 473. Illustrated. Cloth $3.50. Published by John Wiley & Sons, N. Y., 1902.

This book is composed of six distinct parts, each treating of a separate branch of engineering, being the outcome of six lectures delivered at the Cooper Union in New York city, in February and March, 1902.

Part 1—takes up the early history of the civil engineering works of the ancients. It is pointed out that civil engineering is of great antiquity, although much of the real engineering works are, in historic literature, classed as architecture The growth of engineering is then traced, historically, from the earliest efforts at drainage and irrigation and the first attempts of building with bricks and stone, among the Chaldeans and early Egyptians, down through these ancient times to the old Roman triumphs. Following this, the famous old Roman roads, the great sewers built about 753 B. C., and the early Roman bridges and aqueducts are described in detail.

Part 2—is a study of American bridges. After a brief historical account of the growth of bridge building in this country, the theory of bridge design is considered and some methods given for solving the problems that arise in modern structures. The ribbed arch, the masonry arch, and concrete re-inforced with steel are considered. The closing chapter is devoted to cantilever bridges and stiffened suspension trusses.

Part 3—considers the water supply for cities and towns. The consumption and waste of water is considered, together with the sources of water supply and the methods of conducting the water to where it is needed. The theory of the flow of water in pipes is briefly outlined, and some methods of filtration described and illustrated.

Part 4—takes up some features of railroad engineering. Train resistance, grades, curves, road beds, and location of lines, are briefly explained The modern methods of train signalling are explained and illustrated in considerable detail. Some of the largest and some of the fastest locomotives are described, with a comparative table of proportions.

Part 5—contains a very interesting historical account of the exploration and early navigation of Lake Nicaragua and of the first projects for connecting the two oceans by a passage across the Isthmus at this place. A detailed account is given of the nature of the country, and what has been done by different companies that have been formed to consider the feasibility of a ship canal The canal as proposed by the U. S. Government is explained and some ideas given as to the magnitude of the enterprise; and of the cost in detail.

Part 6—is an account of the Panama Canal showing what has been done by France and explaining what still remains to be accomplished. The topographical features of this line are also considered in detail and the nature of the work that must be carried out is illustrated. The book closes with a comparison of the two routes.

This book is written in a very entertaining style and the illustrations are especially fine. The principal criticism that might be offered on the book as a whole, is the wide diversity of subjects. While as a library book this would perhaps not be an objectionable feature, it would seem that for the general reader a division into at least three volumes would have been preferable. J. N. H.

The Textile Fibres of Commerce. By Wm. I. Hannan. London, Chas. Griffin & Co. Philadelphia, J. B. Lippincott & Co. Price, $3.00. 8vo., 236 pages, including index. 149 illustrations

Textile fibres may be classified as vegetable, animal and mineral, of which by far the greatest variety used by man belong to the vegetable kingdom.

The animal fibres include the silk of cocoons of various insects, the hair and fur fibres of different animals, as well as the wool of sheep and goats.

Mineral fibres are those of asbestos.

The vegetable fibres are classed as:

1. Plumose—those attached to seeds (cotton for example).
2. Stem and leaf fibres, as hemp, flax, etc., and,
3. Fruit fibres, such as are obtained from the covering of the cocoanut.

By far the greatest amount of vegetable fibres used in textile industries are the plumose fibres, which include several others than cotton fibres, but the stem and leaf fibres some of which are called bast, are also of great value. Flax and hemp head this list. Cotton fibre is the one most in use by mankind, and receives the most attention by the author, though much is left unsaid. The introduction of special "shop terms" in the text, and without explanation or glossary, is a drawback for the general reader. Illustrations show the cotton plant and leaf, the bolls or capsules of different varieties of cotton, the fibres magnified; also examples of the spun or woven fibre in various stages are shown.

The "bast" fibres, which are obtained from beneath the bark of the stems of some plants, or in the substance of the stem or leaf, are in great number, though secondary to cotton fibre in tonnage. Flax and hemp lead this list, but "manila" fibre obtained from a variety of banana, is of great commercial importance. A competitor of the manila hemp for cordage is the sisal hemp obtained from Agave, of Central America.

Flax and hemp (not to be confounded with each other as they are two distinct plants and fibres) are associated from a certain correspondence between the characteristics of the plant, the fibre, and its recovery; the illustrations showing these plants, the fibres and fabrics, etc. To one who has read and appreciated the picture of Kentucky hemp cultivation and harvesting in "The Reign of Law," by James Lane Allen, the mention of hemp will bring to mind pleasant memories.

Ramie is a fibre grown in China, Java and the Pacific Isles, that possesses some very valuable qualities, but though many experiments have been tried, it is of commercial value to the English manufacturer to but a limited extent.

Jute, from the East Indies, is of much commercial value for sacking, twine and rope. The soft twisted string used by the postal clerks to tie up their bundles of mail matter is of jute fibre.

Considerable space in the book is given to the subject of silk—an animal fibre—spun by the caterpillar or larva of various varieties of the Lepidoptera There are many illustrations of the moth, cocoons and fibres. An artificial silk, which is not a silk at all, has been made from wood pulp by chemical and mechanical processes and has been used to a limited extent in weaving, as a filler or weft, in connection with a cotton warp. The animal fibre, wool, is described and illustrated at considerable length, as is right, considering the value of this material. The classification of sheep and their wools, the sorting and grading of staples, the special characteristics of notable wools, the character of the fibre as shown by the microscope, etc., etc,, are here stated and with many illustrations.

Other animal fibres are considered, including hairs, bristles, furs, etc., but lack of space forbids.

The book is more of a dictionary for reference than a treatise and is disappointing in its lack of logical arrangement and treatment. It is of value as a reference book to look up any special fibre. W.

Steam Power Plants, their Design and Construction. By Henry C. Meyer, Jr. M. E. McGraw Publishing Co., New York. 8vo., 160 pages, 16 plates and 65 illustrations. Price, $2.00

This recent work is one of the best little books on this subject that has appeared. It is compiled largely from a series of papers that have been printed in Engineering Record but with some valuable additions. The work is not too technical to require an engineering education to comprehend it, and for this reason it should be welcome and readily understood by engineering students and business men for whom it was written The book contains such information as to enable the average man of business who lacks the leisure for prolonged study of engineering problems to obtain an intelligent idea of what is necessary for his power plant.

It consists of eleven chapters, of which Chapter 1 contains general information on location of power plants, with notes on foundations for power houses as well as for engines.

Chapter 2 gives information on boilers, describing types, proportions, horse power required for the work to be done, proper grate area for various fuels, anthracite or bituminous coals, etc. There is also a short but well written description of the various kinds of coal to be had in the open market.

Chapter 3 treats of the design and construction of steam boilers. The boiler part is the most important one in a power plant. Without boilers well designed and constructed and properly installed there will always be trouble and annoyance, for no power plant can be better than its source of steam power, the boiler and its accessories, for too frequently it is the one part of the plant that gets the least consideration. The boilers, their construction, fitting and erection should have an equal chance with the rest of the machinery.

The author gives some valuable tables and specifications for the design and construction of boilers. A boiler setting particularly adapted for the combustion of bituminous coals to be found in the western market is shown in plate 4, and is by Dr. E. D. Leavitt, consulting engineer, Boston, Mass.

Chapters 4 and 5 relate to steam engines, the selection of types for service demanded, steam pressure, relative speed, mean effective pressure, proportions of cylinders for simple and compound engines, variable loads and overloads, superheated steam, steam jackets, etc , etc., with detailed specifications for steam engines.

Chapter 6 treats of the sizes of steam pipes and flanges and the general construction and erection of the steam mains.

Chapter 7 treats of sizes and types of condensers, sources of water supply, cooling towers for the same, with general specifications.

In Chapter 8 the subject of feed water heaters and fuel economlzers is considered, with costs and economy resulting from their installation, and also of the purification of the feed water for the boilers.

Chapter 9 relates to the theory of combustion and mechanical draft with its advantages, etc.

Chapter 10 takes up the subject of chimneys, their design and construction, and is especially well written. The height necessary to secure a good draft and the proper proportions agrees with the writer's own experience. Here the author goes a little deeper into the mathematics of construction and there are several illustrations, with dimensions of some notable chimneys, constructed of various materials. The author especially impresses the readers with the necessity of height to secure the draft for the best results of combustion.

The final Chapter, 11, takes up the subject of coal handling, and gives the costs of boiler room labor. The general subject of methods of purification of water is also well considered.

Throughout the book, the plates showing various power plants, are of much interest, and are sufficiently full and clear that the absence of detailed description of them can be excused. These plates show work that has been actually constructed by many very able engineers, and will serve as examples as to ideal power plants. J. H. G.

Trades Waste, Its Treatment and Utilization, with special reference to prevention of river pollution. By W. Naylor. London, Chas. Griffin & Co. Philadelphia, J. B. Lippincott Co. 1902. 8 vo., 267 pages, including index. 21 folding plates and 139 cuts. Price, $6.50.

This is an English book and gives a statement or summary of English practice. The title is somewhat misleading, as there is but little of the utilization of the waste material of various industries considered.

The pollution of streams, by emptying into them the results of industries connected with our modern civilization, is under the care of the English government. This applies even if the waters of any given stream are not used for domestic supply. The destruction of the fish in any stream by the pollution of the waters thereof is of importance, and measures are considered as to the avoidance or amelioration of the nuisance

The trade wastes considered are those from various processes of manufacture, and are water borne, consisting of organic matter of all kinds in solution or suspension, of acids or alkalies in solution, of oily or fatty substances carried by the water, and of earthy or mineral matter suspended and swept along by the current, *sewage*, in short, of a most varied character.

The wastes considered are those liquid outflows from woolen mills, tanneries, breweries and distilleries, dye works, print works, paper mills, gas works, collieries, etc., etc.

The author states that these multiform and complex materials may be so modified that the final discharge of the liquid results will have the least objectionable effect upon the streams or water courses into which they empty.

In a general way the process is to remove the heavy particles by precipitation that otherwise are carried along by the water, to neutralize the acid or alkali constituents of the waste liquors, to remove the suspended organic matter, and to filter on some form of filter bed or otherwise, the liquids to render them as harmless as possible.

The plates illustrate various forms of precipitation tanks and filters which have been introduced here and there for the above purposes. The use of various chemicals, particularly of lime, is explained as assisting in the precipitation of much objectionable matter as well as in neutralizing the acid element from certain processes.

The sludge obtained from the precipitation tanks or filters, does not, as a rule, have much value, but it is a waste material which can be more readily disposed of. The use of septic tanks for the oxidation of organic matter in the liquids has been successfully employed in some cases.

The book should be of interest and value to sanitary engineers. W.

Engineering Contracts and Specifications. Including a Brief Synopsis of the Law of Contracts and Illustrative Examples of the General and Technical Clauses of various kinds of Engineering Specifications. Designed for the use of Students, Engineers and Contractors. By J. B. Johnson, late Dean of the College of Mechanics and Engineering, University of Wisconsin. Third edition, revised. New York, Engineering News Publishing Co. Cloth; 6x9 in.; pp. 566.

The great field covered by the title will be found by noting the index of this valuable work, and the use of this volume by the teacher in engineering schools will indicate to him the fundamentals on law and specifications which should be taught to the student preparing for the actual battle of life.

Theoretical engineering as given to the graduating engineer seems to lack mating with the practical and the young engineer is as a little bark launched upon a sea of troubles and fitted out with plenty of sail area for a light draft to which only experience will give a greater depth and judgment render stability. The teacher must equip his young bark more fully to the trade in which it is to be engaged and should develop his class by a text-treatise upon the law and specifications of his own division of engineering, using this synopsis as the fundamental; assured that there is no better basis except the private collection of a practicing engineer.

Bearing in mind the "Best 25 Books" for the library of the young engineer, we would place this synopsis in a prominent place beside "Materials of Construction" by the same deservedly popular author who has done so much to forward the inked knowledge into a profession.

The practical engineer will in his experience collect "specifications" he has used in his own division of work to the purpose of his own advancement, but will always be able to turn to this synopsis with advantage.

The contractor on construction will find this book of great advantage to his craft and worth many times his $3.00 and the time consumed in study of contents, before signing an ill-drawn contract with its pitfalls and misunderstandings, from which his only escape is over the bruised body of the "inspector." This seed pointer should not fall upon "base rock," but should bear fruit of some friendships otherwise forfeited and scorched into relationships of enmity with the engineer in charge.

When the war begins the contractor will seek the lawyer in whose library he should find a copy of this synopsis beside "Chitty on Contracts." If not so found the contractor should further seek for an attorney for the "party of the second part."

To all of the above mentioned members of various crafts this book will be found extremely serviceable. F. P. K.

A Treatise on Roads and Pavements, by Prof. Ira O. Baker, University of Illinois. New York, John Wiley & Sons, 1903, 6x9 inches. 655 pages, 171 figures. Cloth. Price $5.00.

This recent work by Prof. Baker is one that will be greatly appreciated, not only by engineers who have to deal with the subject, but by that great body of intelligent and progressive citizens who have at heart any subject which has for its ultimate object the uplifting and betterment of humanity. That this treatment of the subject by Prof. Baker will give a great impetus to the subject of good roads wherever it is read and studied cannot for a moment be doubted. As to its effect upon the interest that will be felt upon country roads will this author's treatment be especially valuable. The education of the people to the importance of good roads and their efficient construction and management is of prime importance. If the people can but be interested in the deficiencies in existing roads, the task of accomplishing good roads is more than half perfected. In various ways and under different headings does the author seek to demonstrate the undesirability of bad roads. To many this subject would appear so obvious that its discussion would seem as inane. Yet the great fact remains that to interest the people in the advantages of *good* roads the disadvantages of the poor ones must become manifest, and to accomplish this has been the work of the good roads associations, good roads conventions, and good roads literature in various forms. That the literature on the subject has received its greatest acquisition in "Roads and Pavements" is quite certain. The author has been both painstaking and conscientious, and has undoubtedly been untiring in his efforts to cover all the essential details of the subjects treated. It will become the standard work on roads and pavements in this country.

The typographical features of the book are all that could be desired in a work of this nature. Its index is full and complete, many subjects being cross indexed, which is a desirable feature. H. H. J.

The Romance of the Colorado River, by Frederick S. Dellenbaugh. G. P. Putnam's Sons, New York and London, 1902. 8vo, 400 pp. including index; fully illustrated. $3.50.

This is an account of the discovery and explorations of the Colorado River and the tributary region of the southwest, beginning with the reports of the early Spanish explorers in 1540.

The author, who was a member of Major Powell's second Colorado River expedition in 1871 and 1872, makes special reference to this voyage of Powell through the Grand Canyon. While the book cannot be considered a technical work, nevertheless a knowledge of the history, the geology, the odd life and peculiar conditions of Arizona and New Mexico is of practical interest and value to all who are interested in the development of the arid regions of the West. The knowledge of this forbidding area, now robbed of some of its old terrors by the facilities in transportation, has been finally gained only by a series of persistent efforts, attended by dangers, privations, discouragements, and disasters innumerable Water is the master sculptor in this weird, wonderful land, yet one could there die easily of thirst. Notwithstanding the gigantic work accomplished, water, except in the canyons, sometimes 6,000 feet deep, is scarce. Often for months the soil of the valleys and plains never feels rain; even dew is unknown. Yet in Colorado there is water for the irrigation of thousands of acres, and in the canyons water-power enough to run the machinery of the largest cities. In fact some irrigation work has been made and development of water-power in the Grand Canyon has already been started. The existing mining camps of the region warrant this work.

The second expedition of Major Powell was fitted out partly by the Smithsonian Institution and partly by private subscriptions, among the contributors being the Chicago Academy of Science.

The book is profusely illustrated with photographs of the topography and the Indian: Moki, Zuni, Navajos and Mohave pueblos and life.

The author describes the numerous cliff dwelling and remains of prehistoric irrigation works and buildings. Speaking of the extraordinary ruin called Casa Grande, he says: "This is probably the most remarkable ancient building in the United States. The construction is called cajon, that is, adobe clay rammed into a box or frame which is lifted for each successive course as the work advances. In the dry air of that region such walls become extremely hard and will endure for ages."

The author has shown care and study in the preparation of the book. The numerous foot notes form a most complete index to the literature of the southwest. L. K. S.

THE ESTABLISHMENT OF AN ENGINEERING DIRECTORY.

As one of the functions of the Western Society of Engineers is to promote a feeling of comradeship between its members, and to render assistance to them in their professional work, the Board of Direction have decided to establish what, for want of a better term, may be called an Engineering Directory. The object of this is to bring together those members who may be on the outlook for an engagement and those who desire the services of engineers. It is proposed to do this without cost to the members in the way of charges, fees, etc

The name of the applicant for position will be kept privately by the Secretary and not given out, except as provided for in the rules, and every endeavor will be made not only to render real assistance to those members of the Western Society of Engineers who are out of employment, or who may be in search of more congenial positions, but to render such assistance in the right way.

Attention of employers of engineers, whether members or not, is also called to the exceptional value of this bureau to parties desiring engineering services of the highest order.

Rules to Govern the Conduct of this Directory.

First. Blank applications for employment will be given to any member of the Western Society of Engineers or forwarded to him on receipt of request, accompanied by a self-addressed stamped envelope.

Second. When returned to the Secretary, these applications shall be numbered for identification, and posted on a public file in the rooms of the Society. The name and address of applicant shall be kept on the detached coupon on a private file, numbered the same as the application, and will not be given out except to bona fide employers, and then only when in the judgment of the Secretary no confidence is violated in so doing.

Third. Applications from employers of engineers will be placed on a similar public file, and notifications will be sent to all applicants meeting the required conditions, or to any applicant specially designated by prospective employer.

Fourth. Applications, whether of employers or those seeking employment, shall be kept on file for the two calendar months succeeding the date of appication, and then taken off and destroyed. A brief abstract of each application, identified by number only, and stating character of position sought and salary expected, will be published in the Journal. Any letters addressed to file numbers in care of the Secretary will be forwarded to destination.

Fifth. Applications may be kept on file for a longer period than two months if desired by the applicant, who shall notify the Secretary to this effect by postal card or otherwise. Applicants are also requested to notify the Secretary promptly when the application is to be taken off the file.

It is to be hoped that this arrangement of applications, etc., filed at the offices of the Society, will result in benefit to those members who are seeking a professional engagement.

By Order of the Board of Direction.

J. H. Warder, Secretary.

August 5, 1902.

ABSTRACT OF APPLICATIONS FOR EMPLOYMENT.

No. 13—Feb. 16, 1903.

Position Desired.—Engineer in charge of structural steel work, design and detail work, or chief draughtsman in charge of office.

Experience.—Graduate of technical university, 1892. Important work in office work and on construction of bridge and building work. Now hold position as chief draughtsman.

No 14—Feb. 27, 1903.

Position Desired.—Railroad work (maintenance or construction), or with contracting or manufacturing firm.

Experience.—Graduate civil engineer. Two years as engineer in general municipal work. One year with government engineers. Three years on railroad construction and maintenance. Am now engaged as engineer on maintenance of way.

No. 15—March 28, 1903.

Position Desired.—Railroad work (maintenance or construction), or with contracting or manufacturing company.

Experience.—Graduate civil engineer. Resident engineer, locating engineer, now assistant engineer on maintenance of way.

No. 16—April 21, 1903.

Position Desired.—Designing bridge and structural engineer.

Experience.—A graduate of the Polytechnic School at Karlsruhe, Germany. Draughtsman for three years at Edge Moor; assistant engineer with C. Shailer Smith, one year; assistant bridge engineer C., M. & St. P. Railway, two years; consulting bridge engineer, nine years; assistant engineer of the Manhattan Elevated Railway, three and one-half years.

Positions Open.

The C. & E. I. R. R., Mr. W. T. Dawley, chief engineer, 355 Dearborn street, Chicago, will need some resident engineers for railroad work in Illinois this spring.

WESTERN SOCIETY OF ENGINEERS

SECRETARY'S OFFICE, LIBRARY, READING ROOM AND MEETING ROOMS
1734-41 Monadnock Block, Chicago

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MEETINGS

Regular Meeting—1st Wednesday evening of each month except January, July and August.

Extra Meeting—3rd Wednesday evening of each month except July and August

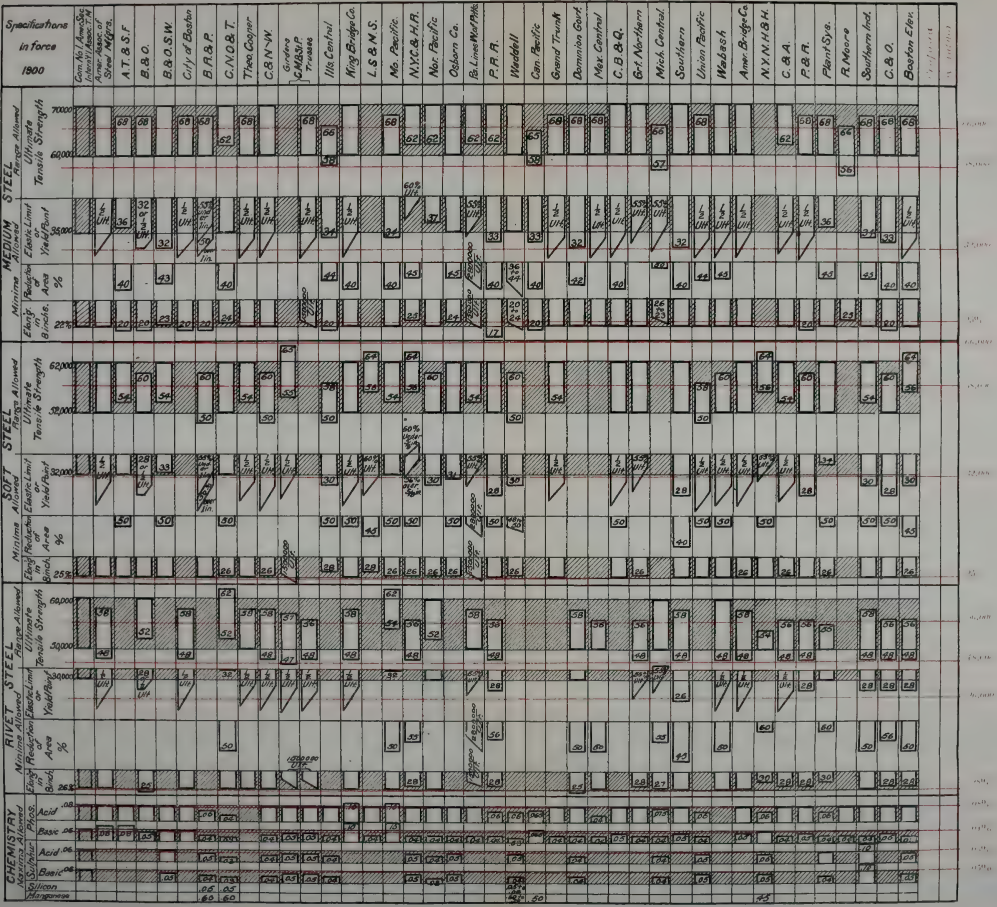
Board of Direction—The Tuesday preceding the 1st Wednesday of each month.

NOTICE

From the dues of each member, $2.00 is set aside as a subscription to the Journal.

SPECIFICATIONS FOR ROLLED STEEL.

Comparison of the Requirements of 39 existing specifications with the recommendations (shown in hatched bands) of the American Branch of Committee No. 1., International Association for Testing Materials.



Journal of the
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VOL. VIII. JUNE, 1903. NO. 3.

CLXXII.

SPECIFICATIONS FOR MATERIAL AND WORKMANSHIP FOR STEEL STRUCTURES

T. L. CONDRON, M. W. S. E.

Presented Jan. 21, 1903.

The subject of specifications for steel and for workmanship for steel structures, has engrossed considerable of my time and attention during the past nine years, owing to the fact that during that time I have been constantly engaged in inspecting material and workmanship under specifications prepared by many engineers representing railroads and other large corporations. In 1901 I prepared a diagram showing the variations in the physical and chemical requirements of a large number of specifications, making a comparison with the specifications proposed by the American Section of the International Association for Testing Materials. This diagram is shown in Plate 1. The red lines on this plate indicate the physical and chemical requirements recommended in the specifications here submitted.

It will be noted that there are a great number of more or less important variations between the specifications shown, and as the purposes for which the steel purchased under these specifications are all similar, it seems only reasonable that a uniform specification should be agreed upon which would reasonably satisfy all users of structural steel for ordinary structures. As it is commercially impossible for the manufacturers to make such a great variety of steel, as is called for by such varying specifications, the manufacturers adopted the well known "Standard Specifications of the Association of American Steel Manufacturers," which provide for the grades of steel, called "soft" and "medium." In order to please as many as possible and at the same time limit rejections under these specifications to a minimum, each grade was given a range of 10,000 pounds in ultimate tensile strength, and these ranges were made to overlap each other 2,000 pounds. Under these specifications it was only necessary for the manufacturer to exercise especial care to have his steel test, so far as possible, in this 2,000-pound range in order to have it pass for either soft or medium steel. As we are all aware, the efforts in this direction have been quite successful. This results in an effort to produce a steel that will test between 60,000 pounds and 62,000 pounds tensile strength. As there is a greater demand for "medium" steel than for "soft" steel, the tendency is to have the steel test above 60,000 pounds rather than below, so that at present it is safe to say that our manufacturers are producing steel having an average tensile strength of about 62,000 pounds per square inch.

The next move toward a uniform specification has been in the direction of eliminating the two grades, and substituting therefor one grade of steel, which has generally been designated as "structural steel."

The specifications I submit herewith for your consideration are based upon a steel having an average tensile strength of 62,000 pounds per square inch, it having been conclusively demonstrated that our American manufacturers can supply such a steel within a reasonable variation. I have specified that the variation shall be limited to 4,000 pounds above or below 62,000 pounds as determined by the usual tests made, but that where the first tests do not fall within this 4,000-pound limit retests will be allowed, the results of which must fall within 5,000 pounds above or below 62,000 pounds, to pass the material.

Another proposition which has met with considerable favor, and has been adopted by several of our leading railroads, is to specify one grade of steel ranging from 55,000 to 65,000 pounds tensile strength, or allowing a variation of 5,000 pounds above or below 60,000 pounds. My objection to this grade is simply that the average is 2,000 pounds lower than there seems any necessity for, and its lower limit is 3,000 pounds lower than seems necessary or desirable for bridge building, where reaming should always be called for. If the working stress of steel is taken at one-half the elastic limit, and the elastic limit is assumed to be 55 per cent of the ultimate strength, then for steel of 55,000 pounds tensile strength the working stress should be 15,000 pounds, while for steel of 58,000 pounds tensile strength the working stress should be 16,000 pounds.

For steel buildings it has been customary to use "medium" steel and not require reaming. This practice has been shown to be safe and satisfactory. It will therefore be difficult to get the approval of many usuers of steel for building purposes to agree upon a steel 5,000 pounds lower in tensile strength than what they have used successfully up to this time. They would more readily agree upon a uniform specification having 62,000 pounds as an average strength, for the majority are now specifying a steel of 64,000 pounds average, or a range from 60,000 to 68,000 pounds tensile strength.

The committee on metal structures of the American Railway Engineering and Maintenance of Way Association, of which committee I have the honor to be a member, has been working upon a uniform specification to recommend to that association for adoption, and while that specification has not been finally passed upon by the committee, there has been a great deal of correspondence on the subject, and there is good reason to hope that at the convention of that association in March next, a specification covering one grade of steel will be recommended for adoption together with a specification covering the general requirements for first-class shop work, so that when a railroad company contracts for steel work it will be possible to state that the material and workmanship shall be in accordance with the specification recommended by the Maintenance of Way Association.* I have thought that a free discussion in this Society of some of the features of the specifications I offer herewith would be helpful toward bringing about a uniformity in specifications for material and general workmanship.

I do not consider that it is desirable to settle upon a specification, and say that it embraces all that is good or desirable and cannot be improved upon, but I do think that it is desirable that those general features of specifications that can readily be standardized, should be made uniform; then as particular cases arise, or new methods are developed, supplementary specifications can be drawn by engineers to cover the special requirements of such cases. One other argument in favor of a uniform specification is, that in the mills and shops the elaborate and detailed specifications prepared by engineers are never seen by the men actually engaged upon the work. All that reaches them are the brief extracts shown upon the mill orders or working plans, and such general instructions as may be given to foremen by the manager or superintendent, or the inspectors. In many instances the engineer's specifications do not get beyond the contract agent of the bridge company. If, however, work is contracted for, to be in accordance with a well known, or so-called "standard specification," the men in the mills and shops at once know what is required and generally work accordingly.

I do not claim much originality about the specifications submitted herewith, except as to arrangement and selection, and in a few instances an attempt to improve or abbreviate the language used, so if you all recognize familiar clauses, perhaps first used in your own specifications, I trust the clauses will meet your approval; but perhaps there will be some that your experience has taught you are undesirable and should be eliminated or changed, in which case I hope you will freely criticise.

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*Since this paper was read the Committee referred to has submitted a specification and the same has been adopted by the Association. See *Railway Age*—March 20, 1903; *Engineering News*, March 26, 1903.

In conclusion I wish to advocate the reaming and planing of all steel used for main members and connections of bridges, for in my opinion it is money well spent, whether the bridge be for highway or railroad traffic. The superior fitting together of the parts secured by reaming insures increased strength of the whole structure, and the removal of the injured metal around the rivet holes, and on the sheared edges is the greatest safeguard against failure from shocks. Last summer three car loads of bridge material, including top chords, end posts, stiff bottom chords, and stringers for a 150-foot span designed by me and built under my specifications, were in a railroad wreck. The cars were thrown down an embankment and the details of the members badly bent and twisted. A careful examination of all this material failed to discover a single cracked plate or angle, although in some cases the material had been bent nearly double. The material was 60,000 to 68,000 pound steel and all rivet holes had been punched $\frac{11}{16}$-inch and reamed to $\frac{15}{16}$-inch diameter. Frequently I have seen the same kinds of material and quite as often "soft" steel, that has developed cracked angles and plates, in the rough handling during erection. In these cases, almost without exception, the cracks have been through unreamed holes.

I submit the following for your consideration and discussion:

SPECIFICATIONS FOR STRUCTURAL STEEL FOR BRIDGES, BUILDINGS, ETC.

MATERIAL.

PROCESS OF MANUFACTURE. 1. Steel shall be made by the open hearth process.

CHEMICAL AND PHYSICAL PROPERTIES.† 2. The steel when tested as described in paragraphs 3 to 9, inclusive, shall show the following properties:

STEEL	Max. % Phos. Ba.	Max. % Phos. Ac.	Max. % Sul.	Ultimate Tensile Strength (desired) Lbs. per sq. inch	Minimum Yield Point Lbs. per sq. inch	Minimum Elongation %	Minimum Elongation In	Character of Fracture	COLD BENDS
(a) Rivets	.03	.06	.04	52,000*	25,000	28	8″	Silky...	See Paragraph 4.
(b) Plates, Shapes and Bars	.04	.08	.05	62,000*	32,000	25	8″	Silky...	180° flat.
(c) Eye Bars (specimen)	.04	.08	.05	66,000*	36,000	22	8″	Silky...	180° around a diameter of 1 in.
Eye Bars (full size)	.04	.08	.05	62,000	30,000	15	10′	Silky...	
(d) Pins and Rollers ..	.04	.08	.05	70,000*	35,000	22	2″	Silky...	180° around a diameter of 1½ in
(e) Castings	.04	.08	.05	70,000*	35,000	18	2″	Silky or Crys.	90° around a diameter of 1 in.

* Steel testing, on first test, within 4,000 pounds of the desired ultimate will be accepted. Steel testing on first test, more than 4,000 pounds and not over 6,000 pounds above or below the desired ultimate, may be retested on the same gauge. Two retests shall be made, both of which must test within 5,000 pounds of the desired ultimate to be accepted.

† See table given in closure to the discussion of this paper on page 271.

CHEMICAL ANALYSES. 3. A chemical analysis shall be made by the manufacturer from a test ingot taken at the time of the pouring of each heat of steel, and a correct copy of such analysis shall be furnished to the engineer or his inspector.

PHYSICAL TESTS. 4. Rivet rods shall be tested as rolled. Rivet steel, when nicked and bent around a bar of the same diameter as the rivet rod, must give a gradual break and a fine, silky, uniform fracture, and not a sudden break with a square, crystaline fracture.

5. Plates, shapes and bars shall be tested by cutting from the finished product coupons which shall be milled into the form of the standard test specimen, Fig. 1; or they may be turned down to a diameter of ¾-inch for the length of at least 9 inches with enlarged ends; or they may have their sheared edges planed parallel.

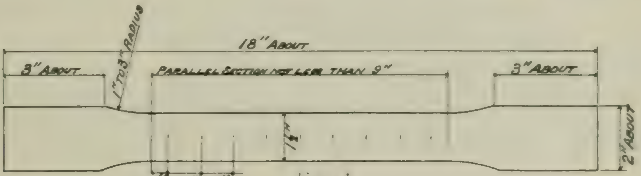


Fig 1.

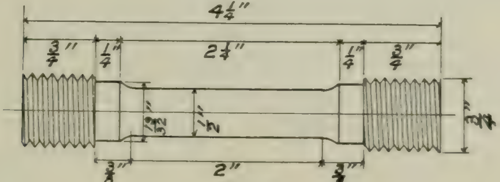


Fig 2.

6. Eye bars shall be tested by specimens the same as plates and shapes. Full size tests shall be made only when specified in the contract.

7. Pins and rollers shall be tested by cutting specimens from the finished rolled or forged bar, the center of which specimen shall be 1 inch from the surface of the pin or roller. The specimen for tension test shall be turned to the shape and dimensions shown in Fig. 2. The specimen for the bending test shall be 1 in. by ½ in. in section and may be bent by blows or by pressure.

8. For castings, the number of test specimens shall depend upon the character and importance of the castings. A test piece shall be cut cold from a coupon to be molded and cast on some portion of one or more castings from each melt or blow or from the sink-heads (in case heads of sufficient size are used). The coupon or sink-head must receive the same treatment as the casting or castings before the specimen is cut out and before the coupon or sink-

head is removed from the casting. The shape and dimensions of test specimens shall be the same as for pins.

NUMBER OF TESTS. 9. At least one tensile and one bending test shall be made from each melt or heat of steel as rolled. Steel more than 25 per cent thicker or thinner than that tested shall be separately tested. (Note.—Material from ⅜ to ⅝-inch thick would pass on the test of ½-inch material, but ¾-inch material would not.) Separate tests shall be made for: (1) plates; (2) angles and Z bars; (3) beams and channels; (4) bars and rods.

FINISH. 10. Finished material must be free from injurious seams, flaws, cracks or other defects, and have a workmanlike finish.

STAMPING. 11. Every finished piece of steel shall be stamped or rolled with the name of the manufacturer and the grade of steel, also with the melt number. Steel for pins and rollers shall be stamped on the end.

12. Rivet and lacing steel and other small pieces, where necessary, may be shipped in bundles with the melt number on a tag attached.

DEFECTIVE MATERIAL. 13 All material which, subsequently to the above tests at the mills, and its acceptance there, is discovered to have injurious flaws, or under the shop punching or shearing or other manipulation, develops weak spots or brittleness, cracks or other imperfections, shall be rejected at the shop, and such material must be replaced by the contractor at his own cost.

ALLOWABLE VARIATION IN WEIGHT. 14. A variation in cross-section or weight of each piece of steel of more than 2½ per cent from that specified will be sufficient cause for rejection, except in the case of sheared plates, which will be covered by the following permissible variations, which are to apply to single plates:

15. Plates twelve and one-half pounds per square foot or heavier, when ordered to weight, shall not vary more than 2½ per cent above or 2½ per cent below the theoretical weight.

16. Plates under twelve and one-half pounds per square foot, when ordered to weight, shall not vary more than the following:

17. Up to 75 inches wide, 2½ per cent above or 2½ per cent below the theoretical weight.

18. Seventy-five inches and over, 5 per cent above or 5 per cent below the theoretical weight.

19. For all plates ordered to gauge, there will be permitted an excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the following table:

TABLE FOR ALLOWANCES FOR OVER-WEIGHT FOR RECTANGULAR PLATES WHEN ORDERED TO GAUGE. 20. The weight of one cubic inch of rolled steel is assumed to be 0.2833 pound.

Thickness of Plate. Inch.	Width of Plate.		
	Up to 75 Inches. Per Cent.	75 to 100 Inches. Per Cent.	Over 100 Inches. Per Cent.
¼	10	14	18
$\frac{5}{16}$	8	12	16
⅜	7	10	13
$\frac{7}{16}$	6	8	10
½	5	7	9
$\frac{9}{16}$	4½	6½	8½
⅝	4	6	8
¾	3½	5	6½

WORKMANSHIP.

CHARACTER OF WORKMANSHIP. 21. All workmanship must be first class in every respect, and up to the latest practice in modern bridge works. Lack of facilities will be considered no excuse for furnishing poor or inferior work.

STRAIGHTENING MATERIAL. 22. All material shall be thoroughly straightened in the shop by proper appliances before being laid off or worked in any way.

SHEARING. 23. All shearing of plates and angles shall be neatly done. All gusset plates shall be cut so as to leave no projecting corners. All edges and ends of parts in built members shall be cut true to line and flush with each other or be dressed after assembling.

FILLETS. 24. No sharp unfilleted re-entrant angles will be allowed anywhere, and wherever plate, angle or shape has been cut into, the fillet as well as the cut must be so finished that no sign of the punched or sheared edge remains.

RIVETS. 25. Unless the rivet holes are to be drilled, rivets must never be of less, and will preferably be of greater, diameter than the thickness of the thickest piece they are to connect, except in the case of sole plates or parts not transmitting stress.

26. The size of rivets called for on the plans shall be understood to mean the actual size of the cold rivet before heating.

PUNCHED HOLES. 27. For all unreamed work the diameter of the punch shall be not more than $\frac{1}{16}$ inch greater, nor the diameter of the die more than ⅛ inch greater than the diameter of the rivet.

SPACING OF RIVET HOLES. 28. All punched holes shall be so accurately spaced that when the parts of any member are assembled, all of the rivets may be easily inserted. Any corrections necessary shall be made with reamers. No drifting to enlarge unfair holes will be allowed. Poor matching of punched holes will be sufficient cause for rejection at the option of the inspector.

ASSEMBLING. 29. All surfaces that are to be in contact or will be inaccessible after the parts are assembled shall be given a coat of approved paint. (See paragraph 60.)

30. Riveted members shall have all parts well pinned up and drawn together with bolts before reaming or riveting is commenced.

STIFFENERS. 31. All stiffeners shall fit neatly between upper and lower flanges of girders. Special care shall be taken to get a tight fit at the upper ends of all stiffeners in deck girders and the lower ends of stiffeners over end bearings in all girders.

FILLERS AND SPLICE PLATES. 32. All fillers under stiffeners and all splice plates shall be cut straight and square at the ends, and not fall back more than ⅛ of an inch from flange angles. All holes or pockets where water might collect must be avoided.

LATTICE BARS. 33. All flat lattice bars with single rivets, unless otherwise called for, shall have neatly rounded ends concentric with the rivet hole, and their ends must not project beyond the flange to which they are attached.

WEB PLATES. 34. Web plates of girders which have no flange plates shall be flush with the backs of angles or project above the same not more than ⅛ inch, unless otherwise shown in plans. When web plates are spliced, not more than ¼ of an inch clearance between ends of plates will be allowed.

CONNECTION ANGLES. 35. All angles or bent plates used as end connections on girders, floor beams or stringers, shall be so accurately fitted that when the member is milled to length, not more than $\frac{1}{16}$ of an inch will be taken off these connection angles. (See paragraph 43.)

RIVETING. 36. All rivets shall be driven by pressure tools where possible, and for rivets with more than one-inch grip a machine capable of exerting a direct pressure upon the rivet, irrespective of the thickness of the pieces being riveted, will be preferred. Pneumatic hammers will be preferred to hand driving.

37. All rivets must look neat and finished, with heads full, and of equal size, central on shank, and grip the assembled pieces firmly. No recupping or caulking will be allowed. All loose, burned, or otherwise defective rivets shall be cut out and replaced. In cutting out rivets, great care must be taken not to injure the adjacent metal. If necessary, they must be drilled out.

TURNED BOLTS. 38. Wherever bolts are used in place of rivets, the holes shall be reamed true to size after the work is assembled, the bolts shall be turned to a driving fit and their threads reduced $\frac{1}{16}$ of an inch in diameter under the size of the finished bolts, to prevent destroying the thread in driving. A small washer not less than $\frac{1}{4}$ of an inch thick must be used under the nut.

STRAIGHTENING FINISHED PARTS. 39. All finished members built or rolled shall be made straight and free from bends, twists or open joints, and if necessary must be cut apart, straightened and re-riveted. Particular care shall be taken to have all compression members straight before pin holes are bored or ends are milled.

COMPRESSION JOINTS. 40. In all members, except the top flanges of girders, the abutting joints shall be milled true to a perfect bearing unless they are fully spliced.

TENSION JOINTS. 41. In tension members and top flanges of girders, the joints shall be cut or dressed true and straight and fitted close together, especially where open to view.

MATCHING CHORDS IN SHOP. 42. All chord and spliced members that are faced for contact bearing shall be put together in the shop, and after being drawn up into contact at the joints and lined up perfectly with the splice plates in place, must have the field rivet holes reamed to a fit before being taken apart. The assembled parts with their splice plates shall be match-marked, so that they may be reassembled in the final erection.

MILLING ENDS OF BEAMS. 43. All floor beams and track stringers shall be finished absolutely correct as to length, and the outstanding legs of the end connection angles must be in true and parallel planes. Unless special forms are used to hold the end connection angles in correct position during the assembling and riveting, both ends of track stringers and floor beams shall be milled to obtain results desired.

PIN HOLES. 44. All pin holes shall be bored true to gauges, smooth, straight and at right angles to axis of member. In riveted members holes must not be bored until after the member is all riveted up.

45. The distance centre to centre of pin holes must be correct within $\frac{1}{32}$ of an inch, and the diameter of the hole not more than $\frac{1}{50}$ of an inch larger than the size of the pin, for pins up to 5 inches in diameter, and $\frac{1}{32}$ of an inch for larger pins.

ANGLE BRACING. 46. When angles are used for counters, or for lateral or sway bracing, the distance between rivet holes, at opposite ends, shall be made enough shorter than the figured length to insure that the member will be drawn up tight when erected in place.

EYE BARS. 47. All eye bars shall be straight and true to size; they must be free from twists, folds in the neck or head or any other defects. All heads must be made by upsetting. No welding will be allowed. The manufacturer will be allowed to determine the size and shape of head necessary, within reasonable limits, but he shall guarantee bars to break in the body when tested to rupture, and not in the head or neck. Thickness of the head and neck must not vary more than $\frac{1}{16}$ of an inch from thickness of bar.

BORING EYE BARS. 48. Before boring, each eye bar shall be thoroughly annealed and carefully straightened. Pin holes must be in the centre line of bar and in the centre of heads. The distance from centre to centre of pin holes after boring must be within $\frac{1}{50}$ of an inch of the required length. Bars designed to be of the same length shall be bored so accurately in length, that when placed one on top of another, pins $\frac{1}{32}$ of an inch smaller than the pin holes can be passed through the holes at both ends of the bars at the same time. The diameter of the hole must not exceed that of the pin by more than $\frac{1}{50}$ of an inch for pins up to five inches diameter and $\frac{1}{32}$ inch for larger pins.

PINS AND ROLLERS. 49. Pins and rollers after being turned perfectly straight and smooth, shall be entirely free from all flaws. Their finished diameters must be that shown on the plans.

PINS AND PILOT NUTS. 50. The screw ends of pins shall be turned down to receive pin nuts. At least one pilot nut and driving head shall be furnished for each size of pin for each span.

SCREW THREADS. 51. All screw threads must make tight fits in the nuts. All threads shall be U. S. Standard except at ends of pins.

ANNEALING. 52. All steel which has been partially heated, shall be thoroughly annealed, except in case of offset stiffeners and fillers, or unless otherwise marked on plans.

WELDS. 53. No welds will be allowed.

BED PLATES. 54. Roller bed plates shall be planed true and smooth. Cast wall plates shall be planed true to height and with bearing surfaces parallel.

SHIPPING DETAILS. 55. All pins, nuts, bolts, rivets and other small details shall be boxed or crated, so that they can be easily handled in unloading, and to insure against loss or damage.

WEIGHT. 56. The approximate or the scale weight of every piece and box shall be marked on it in plain white figures.

ADDITIONAL REQUIREMENTS WHEN PLANING AND REAMING ARE SPECIFIED.

PLANING. 57. Sheared edges and ends shall be planed off ¼ of an inch, excepting web plates of girders over 36 inches deep, when covered by flange plates, fillers where sheared edges are not seen, and lateral connection plates.

REAMING. 58. All holes for rivets shall be punched at least $\frac{3}{16}$ inch smaller than the nominal size of the rivet (or ⅛ inch smaller on the die side of the hole), and shall be reamed to a finished diameter of not more than $\frac{1}{16}$ inch larger than the diameter of the rivet. (Illustration: For ⅞-inch rivets use a punch $\frac{11}{16}$ inch in diameter and ream hole to a diameter of $\frac{15}{16}$ inch.)

REAMING AFTER ASSEMBLING. 59. Wherever practicable, all reaming shall be done after all pieces fastened together by the same rivets have been assembled. If necessary to take the pieces apart for shipping and handling, the respective pieces reamed together shall be so marked that they may be reassembled in the final setting up. No interchanging of pieces after reaming will be allowed.

REMOVING BURRS. 60. The burrs on all reamed holes shall be removed by a tool, countersinking about $\frac{1}{16}$ of an inch under rivet heads.

REAMING FLOOR CONNECTIONS. 61. All field connections in the floor shall be reamed to a fit while the members are assembled in the shop, or to a hardened steel template not less than 1 inch thick.

PAINTING.

62. Before leaving the shop, all steel work shall be thoroughly cleaned from all loose scale, dirt and rust, and be given one good coating of______________________________well worked into all joints and open spaces.

63. On all riveted work, the surfaces coming in contact shall each be painted before being riveted together.

64. Pieces and parts which are not accessible for painting after erection, including tops of stringers, eye bar heads, ends of posts and chords, etc., shall have two coats of paint before leaving the shop.

65. No painting shall be done in wet or freezing weather unless protected under cover. The paint shall be of such quality as may be specified in the contract.

66. Pins, pin holes, screw threads and other finished surfaces shall be coated with white lead and tallow before being shipped from the shop.

INSPECTION AND TESTING.

67. The contractor shall furnish all facilities for inspecting and testing the weight and quality of all material and workmanship at the mill or shop where material is manufactured.

68. He shall furnish a suitable testing machine for testing the specimens and full size eye bars, as well as prepare the pieces for the machine, free of cost.

69. When an inspector is furnished by the railroad company to inspect material at mills or shops, he shall have full access at all times to all parts of mills or shops where material to be inspected by him is being manufactured.

70. He shall stamp each piece inspected with a private mark. Any piece not so marked may be rejected at any time and at any stage of the work.

71. No material shall be rolled nor work done before the railroad company has been notified where the orders have been placed and arrangements have been made for the inspection.

72. The railroad company shall be furnished complete copies of mill orders and plans, and must be notified in time, so that they may have an inspector on hand to inspect material and workmanship.

73. The inspector shall be given reasonable facilities to check the weights of finished members before shipping. Not more than 2½ per cent excess weight over figured weight will be paid for by the railroad company.

74. If the inspector, through an oversight or otherwise, has accepted material or work which is defective or contrary to specifications, this material, no matter in what stage of completion, may be rejected by the railroad company.

DISCUSSION.

Mr. John Brunner, M. W. S. E.—Mr. Condron has, in the paper presented to the society to-night, touched on a subject about which there are many different opinions. Such a variety of structural steel specifications has been written that at first glance it looks impossible to ever get standard specifications adopted. This variety, in the requirements of the specifications, increases the cost of the work and delays its execution. It is therefore very important to the engineers, the railroads, and the bridge shops that standard specifications should be adopted.

The parts of specifications covering workmanship are not so very different in their requirement and it would be comparatively easy to bring them to one standard of specifications, but when we take up the parts relating to materials, unit stresses and loading, we find that such a difference of opinions exists, that it will take a long time before it is possible to get standards adopted. Before this can be accomplished, it will be necessary for many of the engineers to broaden their views on these questions. The mission of the Engineers Society, where the engineers and manufacturers meet and discuss the engineering questions of the day, is to gradually bring the different opinions closer together and form certain standards which its members, for economical reasons, will soon adopt.

The committee of Iron and Steel Structures of the American Railway Engineering and Maintenance of Way Association has before itself the task of gathering together the various opinions on steel railway bridges and to formulate specifications that will be acceptable to the association. The railroads, consulting engineers, and the structural manufacturing plants are well represented among the membership of the association and the standards adopted will, no doubt, be used very extensively. It is therefore very important that as much light as possible should be thrown on the various questions involved. Mr. Condron has, in his paper, presented to us his views on the specifications for material and workmanship, which is part of the work now before the above mentioned committee, as I understand it, in order to bring out a discussion from the members of this society who are interested in the subject and get their opinions.

I believe that the grades of steel he specifies are of too high an ultimate strength to be adopted by the large railroad systems in the eastern and middle states. These railroads are now using a softer grade of steel than that he specifies. For example, the Pennsylvania railroad system uses a grade of steel of 57,000 pounds ultimate strength; the Baltimore & Ohio railroad, the New York Central & Hudson River railroad, the Lake Shore & Michigan Southern railroad and the New York, New Haven & Hartford railroad use a grade of steel of 60,000 pounds average ultimate strength and the Chicago & North-Western railroad and the Atchison, Topeka & Santa Fe railroad use a steel of 60,000 pounds average ultimate strength for all the riveted work. It will be found by studying the specifications from railroads located in the different parts of the country, that as a general rule, railroads running through or in the neighborhood of steel works districts, use a softer steel for their structures than railroads far away from the steel works. This may be explained by the fact that the further away from mills the steel has to be transported, the more costly it will be, and for this reason a harder steel and lighter sections are used by railroads located far from the mills, or it may be that the engineers for these roads are not so well acquainted with the good qualities of the softer grades of steel as those coming in closer contact with the steel works and bridge shops. It is interesting to study how the different specifications vary in their requirements for steel and for this reason I have made an abstract from forty-eight different specifications now in use by 132,578 miles of railroads in the United States. The number of railroads, the mileage they represent, and the average required ultimate strength of steel is given in the list below.

	Railroads.	Mileage.	Soft Steel.	Medium Steel.
	1	4,265	54,000	62,000
	1	2,949	54,000	63,000
	1	472	55,000	64,000
	2	3,771	56,000	64,000
	3	12,599	56,000	65,000
	1	5,172	56,000	66,000
	1	482	57,000	64,000
	3	7,987	57,000	65,000
	2	2,920	57,000	66,000
	5	6,260	58,000	64,000
	1	920	58,000	65,000
	5	11,525	58,000	66,000
	1	6,828	60,000	64,000
	2	15,938	60,000	65,000
	1	1,076	60,000	67,500
Total	30	83,164		

	Railroads.	Mileage.	One Grade of Steel,
	1	1,469	56,000
	3	9,599	57,000
	1	5,667	58,000
	7	16,827	60,000
	1	1,701	61,500
	4	10,699	64,000
	1	3,452	66,000
Total......	18	49,414	

It is interesting to note that in the last group, twelve roads, representing a mileage of 33,562 miles, use a steel of 60,000 pounds average ultimate strength or under, and that six roads, representing a mileage of 15,852 miles, use a steel above 60,000 pounds ultimate. As noted above, the steel of 60,000 pounds or below is used by some of our largest railroad systems, which have a very heavy traffic and for this reason must keep their road-bed and bridges in the best condition obtainable. Most of the European countries have adopted standard specifications for their structural steel. The following grades are used, according to the bulletin of the European Railway Congress:

Portugal, government regulations of 1891, steel 51,200 pounds ultimate strength.

Russia, government regulations of 1888, steel 50,000 to 64,000 pounds ultimate strength.

Austria, government regulations of 1892, steel 50,000 to 64,000 pounds ultimate strength.

Switzerland, government regulations of 1892, steel 51,200 to 64,000 pounds ultimate strength.

Bavaria, state railways, 1899, steel 52,600 to 62,600 pounds ultimate strength.

Bulgaria, state railways, steel 52,600 to 62,600 pounds ultimate strength.

Roumania, state railways, steel 52,600 to 64,000 pounds ultimate strength.

Italy, 1892, steel 54,000 to 65,400 pounds ultimate strength.

Prussia, state railways, 1895, steel 55,500 to 64,000 pounds ultimate strength.

France, government regulations 1891, 60,000 ultimate strength.

Belgium, northern of Belgium lines, steel 60,000 pounds ultimate strength.

Servia, state railways, steel 60,000 pounds ultimate strength.

England, Great Western railway, steel 58,000 to 67,000 pounds ultimate strength.

It will be seen from this list that the European engineers, with few exceptions, have adopted a steel that has an average ultimate strength of 60,000 pounds per square inch or under.

Mr. Condron makes a statement in the first part of his paper that it is safe to say that our manufacturers are producing a steel having an average tensile strength of about 62,000 pounds per square inch.

The manufacturing plant with which I am connected (Illinois Steel Co.) has accepted approximately 50,000 tons of steel on specifications calling for 55,000 to 65,000 pounds per square inch ultimate strength, on which 4,202 test reports are on file. The following is the percentage for each thousand pounds taken from these test reports:

Per Cent.	Pounds ultimate strength.
7.1	55,000 to 56,000
4.6	56,000 to 57,000
6.4	57,000 to 58,000
7.4	58,000 to 59,000
10.0	59,000 to 60,000
26.9	60,000 to 61,000
18.9	61,000 to 62,000
9.6	62,000 to 63,000
5.8	63,000 to 64,000
3.3	64,000 to 65,000
Total......100 per cent	

The average ultimate strength of this steel taken from these reports is 60,208 pounds per square inch. As to the range, 55,000 to 65,000 pounds per square inch, of the specifications on which the steel was accepted, is wide enough to take in the greater part of both the soft steel and the medium steel; the above is a fair indication of what the mills produce at the present time and shows that when material is ordered to these limits, the average of the material received coincides closely with the average between the limits specified, which is seldom the case when other limits are specified.

Summing up the above facts, we find: First, that our leading railroad systems use a steel of 60,000 pounds, or below, for the average ultimate strength; second, that the majority of the European engineers use a steel of 60,000 pounds or less for the average ultimate strength; which steel we come in competition with in the foreign markets; and third, that our steel manufacturers are at the present time producing a steel of very close to 60,000 pounds average ultimate strength to meet an average of present specifications. If we thereto add that the natural product of the basic open hearth furnaces under ordinary conditions, has an average ultimate strength below 60,000 pounds it looks to be a step in the wrong direction to advocate the adoption of a steel of 62,000 pounds average. If we ever expect to get standard specifications adopted, these specifications must be based on the requirements of the large consumers and the most economical production of the material required. Both of these conditions seem at the present time to point to the use of a structural steel of 60,000 pounds ultimate tensile strength for all ordinary structures. For bridges of over 500 feet span, where the dead weight is large compared with the live load, it may be found more economical to use a much higher grade of steel and special workmanship, but structures of this kind usually are built under specially prepared specifications and should not be taken into account when standard specifications are adopted.

Mr. H. E. Horton—There seems to be a question between Mr. Condron's paper and Mr. Brunner's written discussion as to the average tensile strength of steel. I am reminded that the first steel bridge in the United States was built from steel of 150,000 pounds tensile strength—that was the Eads bridge at St. Louis. The second one, the Glasgow bridge, was built from steel of 80,000 pounds tensile strength, and we have gradually stepped down. The only reason we do not step down to 56,000 pounds or less is that it costs too much money. We have to take what we can get. For instance, our supply of material comes from three mills. One of the mills will tell you that they furnish steel which is commercially good, and that is the end of it. The other mill will talk around the question as to whether it is this or the other, etc., but increased cost comes with low steels with great elongation. The only difference between structural steel of the manufacturer's standard specifications and flange steel is the "quench and bend test," nothing more. The fire-box material goes up another step, and the difference there is essentially a "quench and bend test" and a little more elongation.

Mr. Condron—Chemistry, I understand, is often specified.

Mr. W. T. Curtis—I have often wondered if it would be possible to prevent the material from rusting by keeping it dry until it is finally painted. This would require the protection of the material during shipment and call for the manufacture of it entirely under shelter. It is a fact that commodities less affected by water than steel appears to be, are kept entirely under cover in handling, although as far as the value is concerned, a carload of such protected material is worth no more than a car loaded with structural steel. For instance, we have seen cars loaded with street cars carefully protected with tarpaulins, and it has often occurred to me that if we could keep the steel dry in a similar manner until painted, it would be so much the better. Very often the paint is put on, on top of rust.

Mr. Parkhurst—Perhaps Mr. Condron can tell us whether, in the shops he is familiar with, any effort is made to keep the steel under cover.

Mr. Condron—Yes, in certain shops the steel is kept under cover until it is finished. In other equally well known shops it is under cover only during the actual fabrication. The storage is exposed entirely. I think, however, the tendency is for manufacturers to extend their buildings in such a way as to cover more and more of their material. As to shipping material under cover, that has been done in some rare instances. I remember particularly some plates that were shipped from Chicago for pipe line work, some going west and some north, loaded in gondola cars, which had temporary roofs put over them, and in order to avoid the expense of roofing these cars, on one order the mill undertook to take the alternative of painting the plates, and I witnessed the only effort at painting material in the mills that I have ever seen. The manufacturers afterwards said they would go out of business before they would attempt to paint any more material in the mills. It demoralized the whole institution.

Mr. Sample—Where the material is mostly light, and where reaming is seldom done—in small roof trusses, for instance—would it not be economy to use the lower unit in such cases?

Mr. Condron—The question of reaming and punching is a subject you can talk on for a long while, but in my opinion it does not materially damage steel to punch it, if the material is reasonably thin and soft; nor have I any reason to believe that the punching of material as low as 65,000 pounds is any more injurious than punching material that is 55,000 pounds in ultimate strength. I believe in reaming on railroad bridge work, and I believe in reaming any material that is subject to shock or impact, but I would not advocate reaming roof trusses or the light structures you speak of.

Mr. Parkhurst—It seems to me that the question that was asked was one with reference to what is good practice in designing, rather than anything that pertains to the specification of standard material—standard specifications—and I think that the general practice is to design these lighter structures with a much more liberal margin of safety. If you figure them out with considerable care you will find it takes very small sections to carry the ordinary load.

Mr. Sample—I specially referred to the question of economy. Would you be able to reduce weight of structure?

Mr. Parkhurst—I was under the impression that no one actually cuts down the smaller members of a roof truss to the limit that would be justified by accurate figures. There are connections that have got to be made, and that will require an amount of material which, in the member itself, is large in comparison with what is required otherwise.

Mr. Condron—I believe your road (I. C. R. R.) is using 58,000 to 66,000-pound steel.

Mr. Parkhurst—Those are the specifications we have been using lately. I have never made any very careful tabulation and average of the results of our specimen tests, but an examination of a larger number of them—which I have glanced over somewhat hastily—convinces me that 62,000 is pretty nearly the average. To get an accurate average would take a large amount of work, but we very rarely run below that.

Mr. Condron — In reference to the tables of tests which Mr. Brunner has shown us, it must be borne in mind that the steel represented by these tests was specified to be 55,000 to 65,000 pounds, and therefore no tests above 65,000 pounds were reported. Those of us who are seeing the tests from the mills on all kinds of specifications find that a very considerable number of tests run higher than 65,000 pounds. In looking over some tests which came through my office only today, I noticed a steel of 68,000 pounds, and I should say that over half of those were over 64,000 pounds. I had occasion about a year ago or less — in fact only last summer — to go through the test reports of about 400 tons of material on one particular order. The structures had been specified to have medium steel for the main truss members and soft steel for the floor system, so that these tests were separated. I went through and noted the ultimate strengths and found that over 80 per cent of the tests reported on that particular order were above 58,000 and below 64,000; most of them were below 64,000; quite a number ran between 64,000 and 65,000; but over 80 per cent were from 58,000 to 65,000 pounds ultimate strength. I know that a large number of tests are reported and pass through my hands weekly that would bring the average up above 60,000 pounds. I do not think that Mr. Brunner's table fairly represents the product of the mills today. The mills, if I am not mistaken, that Mr. Horton refers to as furnishing good commercial stuff, will accept the specification of 68,000 pounds if pressed to, but while that table is very convincing, that the average of all was 60,208 pounds, and that 30 per cent was 60,000 pounds, it has left out of the question all the product of steel from 65,000 to 70,000 pounds which the mills are shipping all the time, and I believe still that if Mr. Brunner will go a little further he will find that my statement that the mills are making 62,000-pound steel is correct.

Mr. H. E. Horton—I would like to ask Mr. Condron if he does not understand that the difficulty in getting the 56,000 pounds steel is one of cost.

Mr. Condron — I am told that the normal product of the open hearth furnace is about 57,000 pounds average ultimate strength, and therefore a steel that would average 57,000 pounds would be the ideal steel for basic open hearth, and that would mean economy.

Mr. H. E. Horton — Your specifications require the open hearth process?

Mr. Condron — I am specifying open hearth steel.

Mr. H. E. Horton — My experience has been that when I insist on a certain steel the price goes up, and as I understand it, the special high grade of fire box steel goes up in price for that thing alone.

Mr. Condron — I see why the price should go up, for fire box steel usually runs down to 52,000 pounds and in some cases as low as 50,000 pounds, and the fire box specifications of the manufacturer call for low phosphorus and also great ductility.

As to your statement about the quench test, those who have been making such tests will find that we can often make a quench and bend test where we cannot make a cold bend test; a quench test is not difficult to make. The fact of the matter is, our ordinary structural steels are too low in carbon to have any temper and the heating anneals and removes injury due to shearing, while the quenching in water has no effect on them whatever.

Mr. Brunner — I want to add that this table covers mostly open hearth steel and there is very little Bessemer steel in it. I believe that Bessemer steel would run a little higher in ultimate strength under the same specifications. The little Bessemer steel that is included in these reports has a tendency to raise the average ultimate strength; otherwise it would have run below 60,000 pounds.

Mr. J. N. Hatch—In regard to the specifications for different ultimate strengths, suppose you specify 60,000 or 62,000 pounds—if you use the same factor of safety for the two it would take more steel of the 60,000 pounds strength than 62,000. Is it a fact that with the lower steel you could use a higher factor of safety? Would the structure be more expensive with the lower ultimate strengths than with the higher?

Mr. Condron—That is getting into the matter of designing. I only alluded to the fact that if we use 62,000 pounds steel running down to 58,000 as a minimum, and take the yield point at 55 per cent of the ultimate strength, and then take the working stress at one-half of the yield point you obtain a working stress of 16,000 pounds per square inch; and likewise that of 55,000 pounds is 15,000 pounds per square inch. That is why I have been in favor of the 62,000 pounds steel. They are making it and I think that anybody who is handling tests on specifications including both soft and medium steel, will differ from Mr. Brunner, and find they are getting an average of 62,000 pounds.

Mr. Parkhurst—There is a question of what we shall be justified in accepting as a standard—is it 60,000 or 62,000? You may look at it from that point of view, and if 62,000 is a fair average and we design our structures with that, we have saved 2-62 of the weight of the material and so much in cost, rather than use 60,000 pounds steel. These things are matters for our consideration. When we get those high steels we pay for them.

Mr. Sample—I would like to ask if, in full size tests, the steel will show the ratio of increase in tensile strength? Does not the punching injure the higher steel to a greater degree?

Mr. Parkhurst—The higher you go in steel for ultimate strength the more liable it is to injury.

Mr. J. W. Schaub—As far as the ultimate strength of steel is concerned, I am not very particular whether I use 60,000 or 62,000 pounds steel, although I prefer a steel ranging from 60,000 to 70,000 pounds.

In regard to the cracking of material, when I was connected with a bridge works, we used to notice it in the Bessemer steel, but since we have been using the basic open hearth steel it has almost disappeared. I think that would agree with Mr. Horton's statement. I do not think it depends so much on the reaming of the holes as on the chemistry of the material. I think it is useless to plane those plates unless they are subjected to great stress. The planing of web plates is money thrown away; I have discontinued it in all cases excepting on the plates that are subjected entirely to tension.

Another point I will mention, that is, the clause in Mr. Condron's specification, where he says that the web plates shall be flush with the backs of angles or project above the same not more than one-eighth of an inch. That, to a designer, is an ideal thing, but the trackmen object to it. They would rather have the web plate either flush or below.

Mr. Condron—Do you mean the stringers?

Mr. Schaub—Yes.

Mr. Condron—I recall an instance recently in some field inspection work, where the stringers projected uniformly one-eighth of an inch above, and in going over the ground with the roadmaster I spoke to him about that very point. He replied that the first train that went over the rails would settle that matter, and he seemed to think that was the end of it.

Mr. Schaub — Another point that I think should be included in all specifications is that the stringers should not overrun in length. We have had a good deal of trouble in getting stringers of the right length. In some cases they have had to be taken out and the ends chipped in the field in order to get them into place.

Mr. Condron—I think I am right in saying that in Mr. Horton's shop they have been considering the use of a device for fitting up the ends of stringers between stationary forms to avoid facing.

In one of the eastern shops I noticed they were fitting up stringers between some frames which rose from the floor and were placed at an exact distance apart, and it seems just as good a way of doing it as to mill them, and less expensive.

Mr. Schaub — I think they ought to be made scant.

Mr. Parkhurst — I think that point is well covered by the specifications as they stand, Mr. Schaub.

Mr. Schaub — I fail to note anything in the specifications about making the lengths of stringers scant.

Mr. Brunner—There is another trouble you will quite often find, that is, the angles are not quite square.

Mr. G. E. Thackray, Cambria Steel Co., Johnstown, Pa. (*by letter*) —In the opening portion of his statement the author of this paper makes the following remarks:

"In order to please as many as possible and at the same time limit rejections under these specifications to a minimum, each grade was given a range of 10,000 pounds in ultimate tensile strength, and these ranges were made to overlap each other 2,000 pounds. Under these specifications it was only necessary for the manufacturer to exercise special care to have his steel test, so far as possible, in this 2,000-pound range in order to have it pass for either soft or medium steel. As we are all aware, the efforts in this direction have been quite successful."

From a personal knowledge of this subject, the writer wishes to take exception to the above statement and to explain that the ranges of tensile strength for the two qualities, soft and medium steel, were not made to overlap each other for the reasons given by the author, but they were so drawn in order to represent what was, after careful study, found to be current and good practice.

In addition to this, there is an absurdity in the statement made by the author in which he seems to think that the steel of both classes, or a large proportion of it, can be made within a 2,000 pounds range of tensile strength, whereas everyone acquainted with this subject knows that this is not possible, hence the usual specifications for a range of 10,000 pounds, which, by the way, is that allowed by the specifications proposed by the author, on the pages following his preliminary statement quoted above.

As most of the principal existing specifications prescribe, and steel practice necessitates, a range of 10,000 pounds in tensile strength, how could it be possible to work to a range of 2,000 pounds, in order that the steel shall fall in either class?

As far as the writer's knowledge goes, the manufacture of soft steel and medium steel are separate matters, the aim in each case being to produce as near as may be, the average tensile strength of its grade.

It is well known that slight variations in the chemical composition, manufacture, manipulation or thickness, would cause much more than a difference of 2,000 pounds in the tensile strength, and the hypothesis put forth in this connection by the author is very unreasonable and misleading to those not fully acquainted with the subject.

Mr. S. B. Harding, M. W. S. E. (by letter)—The suggestion relative to quality of material and a uniform specification seems to me to be one which has been long looked for and will be welcome by all manufacturers when same is in daily use. The matter of workmanship, perhaps, more interests the bridge builder and manufacturer, and to this end I have the following suggestions to make concerning this portion of a specification, which would also be welcome standardized.

First, regarding rivets. It would seem to me that the sooner rivets 1-inch and 1¼-inch in diameter are used in heavy work, the easier it will be to accomplish better results; ⅞-inch rivets are used in the 3-inch and 3½-inch legs of angles and in the ⅜-inch thicknesses. The same size rivets are used in 6-inch and 8-inch legs of angles and in thicknesses ¾ inch to 1 inch. I contend that it is practically impossible, with the best makes of riveting machines, to insure tight rivets under the latter conditions, simply because the unevenness of the material clamped together and necessarily the force exerted by a riveting machine to clamp the same tight will react in stretching of the rivet so that under the inspector's hammer, the rivet will show a jar. Almost every manufacturer is able to employ this size of rivets and there will necessarily be fewer of them in the work and much better satisfaction, it seems to me.

Secondly, under the head of riveting and particularly the clause, "All loose rivets shall be cut out and replaced." This seems to me to be something required of the manufacturer which is beyond reason. In the first place, the engineer who designs bridge and structural work puts in rivets according to certain practice, especially in the main members of the work where no one can figure the exact strain coming upon them. In bearing plates and in such places where the necessary number of rivets has been computed, the case is different. Now, it would seem more reasonable to me if specifications would permit of a certain percentage, say five per cent, of loose rivets, or rivets with a small jar in the main members of work remaining, provided that they are otherwise good in appearance. I have seen dozens of inspectors ask to have a good, well-formed rivet cut out because it was a trifle loose, and an ugly looking hand rivet put in the same hole and passed simply because it was a little tighter and probably was so because of the method in which the head is formed, while in reality, it does not begin to fill the hole as well as the original rivet cut out. I well understand that inspectors have no alternative and simply follow the specifications in these respects but if inspection is to raise the standard and quality of workmanship, they ought to take a course that will call out the best in the power of the manufacturers rather than many times antagonizing them with such unreasonableness as is very often resorted to.

Thirdly, the subject of planing. It would seem to me that edges of plates which take computable strain should be planed, and other plate edges not planed, provided shearing is done in a satisfactory way.

Fourthly, in regard to the matter of reaming $\frac{5}{16}$-inch metal removed from the diameter of a punched hole would seem to me excessive and impractical. In the first place, allowing such an amount to be removed will not make a manufacturer careful to make his punchings match perfectly and certainly if this reaming is not done uniformly around the periphery of each hole, it is not of the value intended and it is hard to detect how the punching has been done after the work has been reamed to such an extent. Then, too, these holes will be so small in thick material where $\frac{7}{8}$-inch rivets are employed that it will be next to impossible to clamp work up for reaming close enough but what chips and burrs from reaming will force themselves between the surfaces in contact and thus make inferior work. It would seem to me as a substitute for this clause, one requiring say $\frac{3}{16}$ of an inch reaming and a rule that a rod $\frac{1}{16}$-inch smaller than the hole punched should pass through, say 95 per cent of the punched holes after the work had been assembled. I have seen reamed work considered all right when holes have been mispunched in the tension members of work and sufficient in defect to destroy the whole value of the reaming in the entire piece and still these mispunched holes would only be one in possibly 300 or 400 or 1/4 of 1 per cent and even 1 per cent of imperfections in work would not be considered serious. I mention this to show that with imperfections in punching, the whole value of reaming may be set aside. This is why I suggest a substitute or premium put on good punchings. It would also seem to me that members coming in tension should be reamed throughout, but aside from this, I believe that the work would be no worse off for being punched to receive the rivet. Many specifications permit of plate girder work being punched full size in all the webs and bracing, only reaming the flanges. This would seem to me reasonable, yet I cannot see the reason for reaming compression members when the material is rolled under specifications set forth.

Fifthly, the matter of removing burrs on reamed holes is, I think, of no consequence, as it will be observed when carefully removing a rivet where the burr has not been taken off the rivet hole, the indications of the burr, originally, are not apparent, the hot rivet and extreme pressure having partially melted and partially crushed this burr so that it is not perceptible.

Sixthly, the reaming of floor connections to an iron template or while temporarily assembled, unless for the use of turned bolts, seems to be a refinement and one which does not call out careful workmanship in order to avoid misfits. All manufacturers know that they can get a reasonably good job without this reaming for field rivet work, as easily as they do make the work fit which is assembled permanently in the workshop.

These suggestions are not offered in a spirit of criticism but are offered with a view of lessening the price to the public on this class of work without its being any less valuable to them. Then, too, I believe the suggestions will increase the output of the manufacturer at the same time without the durability and strength of the product suffering as a consequence.

Mr. R. H. Reid, L. S. & M. S. Ry. Co., Cleveland (by letter)—There are a few points where my personal preference is not in exact accord with the proposed specifications, as follows:

Chemical and physical properties. I would specify 60,000 pounds steel for all except rivets and castings, with a 4,000 pounds range each way from this, and I would make the elastic limit 60 per cent of the ultimate. This will give us a steel which will be fully as strong, or even stronger, as far as working strength is concerned, as the proposed steel. I believe it will stand shop manipulation better and I think it can be safely used up to ⅝-inch thick for punching without reaming. I would also specify 28 per cent elongation on standard test piece.

I am aware that these requirements are higher than general practice at present, but have no doubt of the ability of the steel makers to reach them when they turn their energies toward one grade of steel.

In paragraph 37 I would add, "Rivets shall be used in preference to bolts wherever possible."

In paragraph 48, instead of saying "Pins $\frac{1}{32}$-inch smaller than the pin holes can be passed through the holes at both ends of the bars at the same time," I would say, "The pins shall pass through the holes at both ends at the same time without forcing," the idea being that the pins may not be $\frac{1}{32}$-inch smaller than holes in every case.

In paragraph 57 I would say "well worked *into* all joints," instead of "well worked *in* all joints."

With these suggestions I concur in the proposed specifications, and hope that a set may soon be adopted that will be acceptable to all.

CLOSURE BY T. L. CONDRON.

Referring to the discussion by Mr. S. B. Harding, I quite agree with him that it is desirable for designers of bridges for heavy railroad loading to use in their designs 1-inch and 1¼-inch rivets, as soon as the shops are equipped to successfully drive such large rivets. Several of the bridge works are now so equipped and are successfully driving 1-inch rivets. In my opinion, however, these large rivets should only be driven with machines capable of exerting a direct pressure on the rivet during the entire upsetting process. There are pneumatic riveters in use that work on much the same principle as hydraulic riveters, with the added advantage that they are portable, instead of stationary tools.

With reference to his criticism of the requirement that loose rivets should be cut out and replaced, it seems to me impossible to cover this matter any other way in specifications. I fully realize that there are many rivets in a structure which it is not necessary to have absolutely tight, but it is hardly reasonable that wide discretion shall be allowed the inspector or the manufacturer in this particular. It is much safer to require that all rivets be tight, than to endeavor to specify which rivets shall be tight and which rivets may be allowed to be loose.

Mr. Harding's suggestion that the specification permit a certain per cent of loose rivets is one worth considering. But I think this is also a matter that must be left somewhat to the intelligence of the inspector and if he is not competent to determine where rivets must be absolutely tight, it is much safer to insist that all rivets shall be tight, in accordance with the specification.

With reference to his remarks about reaming: There was an error in my paper as originally printed which has been corrected in this issue, and the paragraph regarding reaming now calls for the holes to be punched at least $\frac{3}{16}$ of an inch smaller than the nominal size of the rivet, or ⅛ of an inch smaller on the die side of the hole, requiring that for ⅞-inch rivets a punch $\frac{11}{16}$ of an inch in diameter be used and the hole reamed to $\frac{15}{16}$ of an inch.

I have also added under paragraph 28 regarding the subject of rivet holes, the following clause—"Poor matching of punched holes will be sufficient cause for rejection at the option of the inspector." I know this is a rather indefinite requirement, but I do not think it reasonable to refer to a definite percentage as suggested by Mr. Harding. He suggests that a rule be adopted that a rod $\frac{1}{16}$ of an inch smaller than a hole punched should pass through 95 per cent of the punched holes after the work had been assembled.

With reference to his remarks regarding reaming of floor connections, it is to be remembered that any errors that occur in connections that are to be put together in the shop are quite readily corrected, while if errors occur in field connections and are not discovered until after the work is in the field, these errors will often cause very serious delays and expense, and it is to avoid such trouble that the requirement that the connections shall be reamed to an iron template or while the parts are temporarily assembled, has been put in.

With reference to the remarks by Mr. Reid regarding the use of rivets in preference to bolts, this seems to be a matter of design rather than of workmanship, and these specifications have not been intended to cover questions of design.

I have changed the paragraph with regard to painting in accordance with his suggestion, making it read "well-worked into all joints."

Since the paper under discussion was read in January last, the committee of the American Railway Engineering and Maintenance of Way Association referred to therein, reported a specification for material and workmanship for steel structures to the Maintenance of Way Association at its annual convention in March last, which specification was adopted by the association and has become the standard specification for that association. As stated in the paper, I am a member of that committee and I fully concur in the recommendations made by it. It may, therefore, be proper for me to add here, for the benefit of the members of this Society, some of the more important differences between the specification as offered in my paper before you and the specification adopted by the Maintenance of Way Association.

Under chemical and physical properties, the following schedule was adopted, together with the following variations:

Chemical and Physical Properties.	Structural Steel.	Rivet Steel.	Steel Castings.
Phosphorus Max. . . Basic	0.04 per cent	0.04 per cent	0.05 per cent
Phosphorus Max. . . Acid	0.08 " "	0.04 " "	0.08 " "
Sulphur maximum	0.05 " "	0.04 " "	0.05 " "
Ultimate tensile strength.	Desired.	Desired.	Not less than
Pounds per square inch	60000	50000	65000
Elongation; min. % in 8"	$\frac{1,500,000}{\text{Ult. tensile strength.}}$	$\frac{1,500,000}{\text{Ult. tensile strength.}}$	
" " " 2"	22		18
Character of fracture	Silky	Silky	Silky or fine granular
Cold bends without fracture	180° flat	180° flat	90°

The yield point, as indicated by the drop of beam, shall be recorded in the test reports.

"Tensile tests of steel showing an ultimate strength within 5,000 pounds of that desired will be considered satisfactory, except that if the ultimate strength varies more than 4,000 pounds from that desired, a retest shall be made on the same gauge, which to be acceptable, shall be within 5,000 pounds of the desired ultimate "

The number of tests required is as follows:

"At least one tensile and one bending test shall be made from each melt of steel as rolled. In case steel differing ⅜-inch and more in thickness is rolled from one melt, a test shall be made from the thickest and thinnest material rolled."

While the specification for workmanship differs in several particulars from that shown in my paper, none of these differences are very material.

In conclusion, I am willing to waive my own preference and to recommend and use the specification as adopted by the Maintenance of Way Association, believing that it is to the advantage of all concerned that a uniform specification for structural steel be adopted and used as far as possible, by bridge engineers at this time.

CLXXIII.

AN EXHIBIT OF SOME CURIOUS LATTICE TRUSSES.

By Geo. N. Linday, M W. S. E.

Read Jan. 21, 1903.

I intend to show here a few miniature trusses, of a certain kind, that I have made, for the purpose of satisfying my curiosity as to how they would behave when loaded.

In coöperation with Mr. Eric Swensson, of the American Bridge Co., I have given some attention to this matter for some time, and it might not be out of place to state how it came about that we got started along this line.

About a year ago I had occasion to look over some old railway bridges, and among them was one that was built on what looked to be the multiple system plan. It proved more of a puzzle than I had expected, and the calculations led to such queer results that I thought it might interest some of the members to see what they were.

In Figure 1 is shown a part of the span under consideration. In reality it had sixteen panels in the bottom chord, while the figure shows only six, but otherwise the members were arranged as shown. When anyone has to figure a truss like this, he will naturally start out in the established fashion and try to divide up the span in a number of systems; figure each system independent of the others, and add up the results, where the same members occur in more than one system. The trick is to divide up the span in systems, and that is generally easy enough. The rule is to commence at one abutment, follow up an end post, or other member running into the end panel point, take in the web members as they come along and finally land at the other abutment. The members followed up, together with the chord, constitute one system. But if this rule is applied to the truss shown in Figure 1, it is somewhat surprising to see what the result will be. By trial it will be found that every web member is traced up before the other abutment is reached. This would indicate that there is only one system in the truss; in other words, that it is of the same character as an ordinary Pratt-truss, although, to judge from the profusion of members, it does not look very much like it. That this truss is statically determinate, like an ordinary Pratt-truss, is easily seen if the test of statical determination is applied. It may be stated as follows: For a truss with one stationary and one movable support, there will be, for any arbitrary loading, two vertical and one horizontal reaction, or three in all; and, if there are m members and p panelpoints, the criterion of static determination is the relation

$$2\,p = m + 3.$$

In other words, each panel point supplies two equations, in all 2 p equations, by means of which the unknown elements in stresses and reactions may be found.

The truss shown in Figure 1 has nineteen panel-points, hence supplies thirty-eight equations of equilibrium, while there are thirty-five members and three reactions, in all thirty-eight unknown elements. This shows that the truss under consideration is statically determinate.

Generally speaking, any truss of this make-up with any even number of intersections of diagonals is also statically determinate.

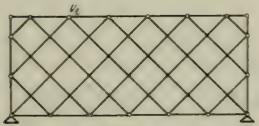


Fig 1

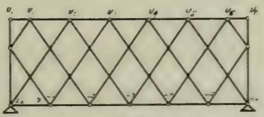


Fig 4

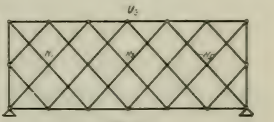


Fig 7

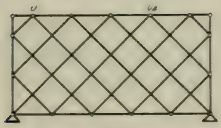


Fig 2

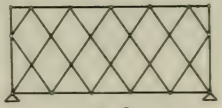


Fig 5

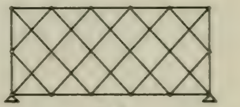


Fig 8

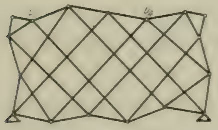


Fig 3

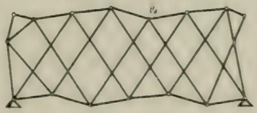


Fig 6

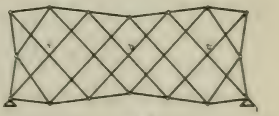


Fig 9

The truss shown in Figure 1 has four intersections, while the ones shown in Figure 4 and Figure 10 have two. It should be stated that this is, of course, true only for such trusses as are built in the way we assume in our calculations, or such as have complete pin-joints at the end of every member, and that the web-members are not connected where they intersect each other, unless they are broken off and complete pin-joints introduced at these intersections.

Even if it can be shown that the truss in Figure 1 or Figure 4 ought to be as easy to figure as an ordinary single system truss, it is another question to find out how to do it. The apparent difficulty lies in the fact that three members meet at the point of support, which makes it uncertain how the reaction divides itself between them. A method to overcome this has been devised,* and may be stated as follows:

It is always possible to remove certain members and introduce an equal number of other members in the truss, and in such manner that there is no ambiguity as to the way the stresses travel in the truss thus transformed.

If in the truss shown in Figure 10 the three top chord pieces are removed and three other members introduced in the manner shown in Figure 11, it is evident that the stresses in this new truss can be figured. It is, of course, assumed that the intersection points where the new members join are complete pin connections.

If now such exterior loads X_1, X_2, and X_3, at present unknown, are applied in the direction of the removed members, as indicated in Figure 11, that the stresses in the introduced members $N_1 N_2$, $N_2 N_3$, and $N_3 N_4$ all become zero, it is plain that such loads X_1, X_2, and X_3 are the stresses sought.

As the stresses in any determinate truss are proportional to the loads producing them, we can apply this rule to the truss shown in Figure 11 and write:

$$S = So + S_1 X_1 + S_2 X_2 + S_3 X_3 \ldots\ldots\ldots\ldots\ldots (1)$$

where S is the stress in any member, S_o the effect on S from all loads except X_1, X_2 and X_3, and the other terms the contribution to S of the unknown loads X_1, X_2 and X_3. The coefficient S_1 is obtained by making S_o, X_2 and $X_3 = O$, and $X_1 = 1$, leaving

$$S = S_1$$

which, in other words, would mean that S_1 is the stress in any member due to a load 1 in place of X_1, while all other loads are removed. The coefficient S_2 and S_3 are defined in a similar manner.

If equation (1) is written for the three members introduced, and put S for each part $= O$, we get three equations which contain the three unknown quantities.

For example, let us take the truss shown in Figure 10 and assume perpendicular intersections of diagonals. For an arbitrary load, say 1, at U_1, Figure 11, the stresses in the introduced members become

So for $N_1 N_2 = +0.25$
So for $N_2 N_3 = -0.50$
So for $N_3 N_4 = -0.25$

Here, and in the following, plus (+) stands for tension and minus (−) for compression. The stresses due to $X_1 = 1$, $X_2 = 1$ and $X_3 = 1$, successively, in the same members, are:

	S_1 for $X_1 = 1$	S_1 for $X_2 = 1$	S_1 for $X_3 = 1$
$N_1 N_2$	$+1$	$+1$	0
$N_2 N_3$	$+1$	$+1$	$+1$
$N_3 N_4$	0	$+1$	$+1$

---

* Muller-Breslau, Grafische Statik.

Hence, applying equation (1) and making S O

$$
\begin{aligned}
0 &= 0.25 + X_1 + X_2 \\
0 &= 0.50 + X_1 + X_2 + X_3 \\
0 &= 0.25 + X_2 + X_3
\end{aligned}
$$

The general solution of this system, expressed in determinants, gives

$$X = \frac{Dx}{D}$$

where

$$D_1 = \begin{vmatrix} -0.25 & 1 & 0 \\ 0.50 & 1 & 1 \\ 0.25 & 1 & 1 \end{vmatrix} \quad D_2 = \begin{vmatrix} 1 & -0.25 & 0 \\ 1 & 0.50 & 1 \\ 0 & 0.25 & 1 \end{vmatrix} \quad D_3 = \begin{vmatrix} 1 & 1 & -0.25 \\ 1 & 1 & 0.50 \\ 0 & 1 & 0.25 \end{vmatrix}$$

and

$$D = \begin{vmatrix} 1 & 1 & 0 \\ 1 & 1 & 1 \\ 0 & 1 & 1 \end{vmatrix} = -1.$$

and finally

$$X_1 = -0.25\,;\ X_2 = +\,0.50\,;\ X_3 = -0.75.$$

It will be noticed that the denominator D is constant for all values of X, and on investigation it will be found that this holds true for a truss of this kind with any number of panels; or, more clearly stated, for any loading applied to a truss of this kind, no matter how many panels it has, the denominator D is constant for that truss.

Generally speaking, it has this form:

$$D = \begin{vmatrix} 1 & 1 & 0 & \dots & \dots & & & & \\ 1 & 1 & 1 & 0 & \dots & & & & \\ 0 & 1 & 1 & 1 & 0 & \dots & & & \\ \dots & \dots & \dots & \dots & \dots & & & & \\ \dots & \dots & \dots & \dots & 0 & 1 & 1 & 1 & 0 \\ \dots & \dots & \dots & \dots & \dots & 0 & 1 & 1 & 1 \\ \dots & \dots & \dots & \dots & \dots & \dots & 0 & 1 & 1 \end{vmatrix}$$

On inspection it is readily found that this determinant becomes zero for a certain number of rows or lines. Such is the case for two, five and eight, etc., rows corresponding to three, six and nine, etc., panels in the bottom chord of the truss. The stresses X would then for this kind of spans become, mathematically speaking, infinitely large, which would mean that a span of such shape would not be capable of sustaining loads at all. An example of such a truss is shown in Figure 4. Under no load, it presents practically the same appearance as the one shown in Figure 5, the difference being seemingly only in the number of panels. If, however, a load, ever so small, be applied at panel-point U_4, the truss will change its form until its assumes a final shape as shown in Figure 6. The truss shown in Figure 5, on the other hand, is capable of sustaining a load at any panel-point, without having its geometrical figure changed.

In tracing up the manner in which the diagonals run in Figure

4, it will be seen that the truss is composed of a complete Warren system, embracing the successive diagonals L_0-U_2-L_3-U_4-L_6, while the other diagonals form a closed figure which does not touch at either of the supports.

Generally speaking, any truss which contains such a closed figure is under certain loadings unstable or collapsible. For a load applied at any point, belonging to the complete Warren system, or for symmetrical and equal loads, the truss does not collapse.

As will be seen from Figure 6, the small four-cornered figures formed by the diagonals have all changed their shape. It follows, that if any two intersecting members are connected at the intersection, a change of form of truss is prevented. This prevention is brought about by the introduction of bending in the members thus connected, in addition to direct stresses communicated throughout the truss. Continuity of chords or end-posts would accomplish the same result. The truss would also be prevented from collapsing by the introduction of a new member connecting any two intersecting points. The same kind of an investigation in regard to trusses shown in Figures 1 and 2 would bring out the fact that trusses of this shape would be unstable structures when the number of panels in the bottom chord is a multiple of five. Thus Figure 2 shows such a truss, and Figure 3 the same truss subjected to loads at U_1 and U_4. All trusses with the number of panels other than five, ten, fifteen, etc., are, on the other hand, stable structures, capable of sustaining loads at any panel-point.

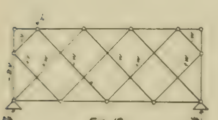


Fig 10

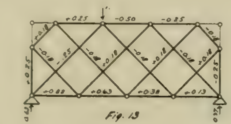


Fig. 13

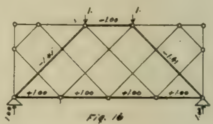


Fig. 16

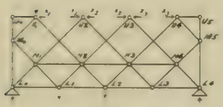


Fig 11

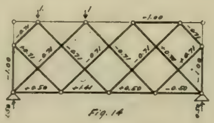


Fig. 14

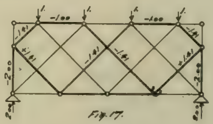


Fig. 17.

Note: Members drawn in light lines in
Figs 12, 13, 14, 15, 16, 17 have no stress.

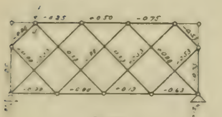


Fig 12

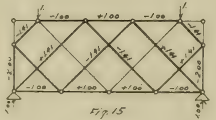


Fig. 15

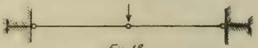


Fig. 18

Not only does this rule hold good for trusses of the outlines shown in the figures, but a modification of these outlines, such as the use of a broken top or bottom chord, does not alter the rule. This is easily found out by making suitable changes in the models, from which the figures shown are line-reproductions.

The method given above for calculating the stresses in any truss of this kind, capable of sustaining loads under all circumstances, is not very well adapted for practical use, but was given for the purpose of pointing out the theoretical reason for the fact that some of these trusses are unstable structures.

An easy method readily applicable is as follows:

Suppose the effect of a load 1 applied as shown in Figure 12 is wanted; in other words, the same case as was treated according to the general method. If the vertical components of the diagonals running into U_1 are v and w, we must have

$$v + w = 1.$$

These same components appear in the other web members, as indicated in Figure 10, and at the left support, for instance, we get another relation:

$$2\,v - w = \tfrac{7}{8}.$$

By adding these two equations we get

$$3\,v = \tfrac{15}{8}, \text{ or } v = \tfrac{5}{8} \text{ and } w = \tfrac{3}{8}.$$

The stresses themselves in these diagonals are consequently

$$\tfrac{5}{8}\sqrt{2} = 0.88 \text{ and } \tfrac{3}{8}\sqrt{2} = 0.53$$

respectively, and in both cases compression as assumed in the figure. It will be noticed by inspection that if the length of one of the long diagonals is taken as unity, the total length of all diagonals is measured by the figure 8; in other words, always by a figure giving twice the number of panels in the bottom chord.

It will also be noticed that the length of diagonals, that the component v has to travel, before it reaches a support, is measured by the figure 3; hence that stress has to travel three-eighths of the total length of all the diagonals in the truss.

But that is just the measure of stress in the diagonal whose vertical component is w, as shown above. Generally speaking, the following rule can be established:

If n is the total relative length of all the diagonals in the truss, and r and l the total relative length of all diagonals running towards the right and towards the left, respectively, from the point of application of a load "P" to their respective supports, then the stress in the former set of diagonals is

$$P.\frac{l}{n}\sec. a$$

and in the latter

$$P.\frac{r}{n}\sec. a$$

where "a" is the inclination of the diagonal to the vertical.

Thus, a load at U_2 in Figure 1 will produce a vertical component in $U_2 L_4$ $\frac{3}{12}$ $\frac{1}{4}$ of the load, and in $U_2 N_0$ it is ¾ of the load. Of course this rule holds good only for trusses with panels of equal length and diagonals of the same inclination.

The stress diagrams shown in Figures 12 to 17 inclusive give an idea how the stresses run under various loadings in a truss of two intersections. It will be noticed how irregular the stresses run, and how a large number of members are not in action under certain loadings, while almost all are subjected to reversal of stresses. Figure 17 is especially peculiar from the fact that it shows the center of the top chord to be without stress when the truss is fully loaded. It is evidently poor economy to use a truss of this kind.

Figures 7 and 8 show trusses with an odd number of intersections of diagonals. In order to find out whether this is a statically determinate truss or not, let us apply the test rule given above.

For the truss shown in Figure 7 there are, for any arbitrary loading, three reactions. The number of members is thirty, in all thirty-three unknown elements, while there are sixteen panel-points or thirty-two equations, by means of which to find these thirty-three unknown quantities. This shows that the truss is singly statically indeterminate, or indeterminate in the first degree; in other words, it shows that as far as this rule holds good, any one member in the truss could be removed and the truss should still be stable under load. This rule is, however, qualified by the requirement, as has already been pointed out in reference to the other trusses, that in the general expression for any stress

$$S = \frac{Ds}{D}$$

the determinant D must not be $= 0$.

But it can easily be proven that D under certain conditions actually becomes zero; and that is the case for all spans of this kind which have an even number of panels, such as the one shown in Figure 7. This truss also contains, the same as the collapsible truss of the other kind, a closed figure of diagonals, while it also contains two systems of sub-trusses which by themselves would be stable structures. For a load applied at the center panel-point of the top chord, the truss in Figure 7 would change its form as indicated in Figure 9. On the other hand, a load placed at any point of the truss in Figure 8 will not only leave it geometrically unchanged, but it is possible to remove any of the members without disturbing its ability to sustain the load applied. There is, however, a radical difference between the unstable truss in Figure 7 and the other unstable trusses described above (Figures 2 and 4). In the latter no resistance is offered to the deformation of the truss until it has assumed such a shape that it is capable of sustaining loads. It will, in other words, move a certain amount, and at the end of that motion become a truss with definite stresses throughout. The truss shown in Figure 7, on the other hand, is a combination of members of the same nature as the link-arrangement shown in Figure 18. For joints of absolutely tight fit, and in case of inelastic material, the center-point when loaded would have an infinitely small motion, while at the same time the pull in the bars would be infinitely large. As a matter of fact, the vertical end-posts on truss, Figure 7, is acted on in a similar manner as the links in Figure 18.

In any structure or model the material is necessarily elastic, and small inaccuracies are present in all joints and lengths. Hence noticeable motions will always occur due to these causes; and, even if the geometrical inaccuracies could be eliminated, the very large stresses developed, even for very small loads, would produce permanent changes in the lengths of the members, or enlargements of the pin-holes, and consequent permanent deformations.

One peculiarity of the unstable truss, shown in Figure 7, is that its tendency to deform is symmetrical, from which fact it follows that a bolt driven through the intersection of the center diagonals will not prevent the motion. Continuity of part of the chords could also be introduced and new members connecting intersections X_1 with X_3 and X_3 with X_5 could be added without stopping the deformation.

This shows that trusses can be made which are many time statically indeterminate and still be unstable structures. Although trusses of the kinds described here are not likely to be used any more, it is well to know that they are structures which it is well to avoid.

DISCUSSION.

Mr. Armstrong—I presume those conditions are entirely changed if diagonal end posts are introduced, and each system will then lead directly to the abutment.

Mr. Linday—Yes; if you make lattice bridges in the way they are usually made, where all the members run directly to the abutments, they will of course stand up.

Mr. Swensson—It ought to be remarked that even if top and bottom chords form any arbitrary curve, instead of being straight as in trusses shown, this will not influence the stability of the truss.

Mr. Linday—As a matter of fact, I made an experiment on that point. I did not know whether a bridge that had a curved top chord would stand up or whether it would collapse, but it behaved in exactly the same manner as those that have straight chord along their entire length.

Mr. Hatch—If the trusses were loaded only at those points which represent the Warren system, would it stand?

Mr. Linday—Yes, it will stand up. Did you not notice that when I hit it?

Mr. Hatch—Then, if you load it with those panels that represent the Warren system, will all the rest of the members be out of action?

Mr. Linday—Yes. This one here that was distorted will stand up if I hit it in the panel point that belongs to the Warren system.

Mr. Sample—Do I understand that the distortion is due entirely to the lack of fitting of the pins, and if that motion were all taken up would there be no distortion at all?

Mr. Linday—In the kind of truss I showed you last, the motion you get is largely due to the lack of fitting of the pins. You can, however, even with tight fitting bolts, move the center point of the end post out a little way without appreciably changing the length of that diagonal. It is a different thing entirely with the other kind. That is a permanently collapsible structure; has hardly anything to do with the amount of play in the bolts.

Mr. Jacobson—I did not grasp the number of panels.

Mr. Linday—If you figure up the number of little square figures in a vertical line, you will get, for instance, here, two and one-half. (Figure 1.) If you have a span that has got, in the bottom chord, a number of panels which is a whole multiple of two and one-half, you get a collapsible structure. For instance, the span in Figure 2 collapses, as it has five panels, five being a multiple of two and one-half. In this other kind (Figure 4) you have one and one-half diamonds, so to speak, in it, and this is collapsible when it contains a number of panels in the bottom chord, which is a whole multiple of one and one-half—three, six, nine, etc. The same thing is true with the other one. Figure 7 has two whole four-cornered figures in a vertical line. This is collapsible for all such structures whose number of panels is a multiple of two.

Mr. Parkhurst—It would seem that you are excluding pretty nearly everything. Then there must be some other limitation.

Mr. Linday—I do not understand just what you mean.

Mr. Parkhurst—If you only count the panels in the vertical height, and if you exclude one and one-half, two, two and one-half, etc., you are not leaving very much.

Mr. Linday—In this particular kind (Figure 7) I leave all the odd number of panels.

Mr. Parkhurst—Well, what are the odd number of panels?

Mr. Linday—This is not the kind that is a multiple of one and one-half.

Mr. Parkhurst—Then there must be some other limitation not clearly expressed.

Mr. Linday—This particular kind (Figure 7) has three intersections of diagonals. It has a number of panels that is a multiple of two, and all such bridges are collapsible. In Figure 1 all such bridges are collapsible which have the number of panels that is a multiple of five, but all these in between are good, substantial structures. That is just a rule to find it out.

Mr. Swensson—The best rule for finding the collapsible trusses is to see if the diagonals form one or more closed figures. If that is the case, then the truss will collapse no matter how many intersections it has.

Mr. Linday—This model here, Figure 1, that is collapsible, has two closed figures, so to speak. There is one complete Warren system to begin with. If I follow this diagonal, beginning at U_1 I get a closed figure, and I come back to the point where I began. Starting out at U_4 I get another. It is a little more work, possibly, to follow up the thing in order to see whether it is collapsible or not by that rule.

Mr. Parkhurst—It would seem that the rule with regard to the closed figure would be the more rational one to try, and more certain in its result.

Mr. Vent—Those in which there are closed figures are not a system of triangles, are they?

Mr. Linday—No, I admit that. It is not necessary that a stable truss shall be composed of a system of triangles exclusively.

Mr. Brunner—I understand that if rivets were used at intersections it would cause bending stresses in the diagonals.

Mr. Linday—Yes, it will cause bending stresses, even in the kind that will stand up, and it is easy to see that it will cause bending stresses throughout in the kind that will collapse.

Mr. Sample—What observations, if any, have you made as to the life of this collapsible type of structure when the intersections are riveted?

Mr. Linday—I have not run across any span of the collapsible kind actually built, so I cannot tell.

Mr. Horton—I have in mind several spans two hundred feet long, five intersections, identical with the model, only they had more panels. However, they had the horizontal members.

Mr. Parkhurst—Would not the introduction of rivets at all intersections make the whole matter very much more complicated, and at the same time make a bridge that was collapsible without the rivets, under one condition, and practically safe with the rivets?

Mr. Linday—I made the remark that that will make a bridge that will not collapse, of course. If you make a continuous top chord I am sure the bridge will stand up, even if you knock out some diagonals. The more elements of indetermination are introduced, the less liable the structure is to collapse.

CLXXIV.

NOTES ON EUROPEAN TRAMWAYS.

By Richard McCulloch, M. W. S. E.

Read April 15, 1903.

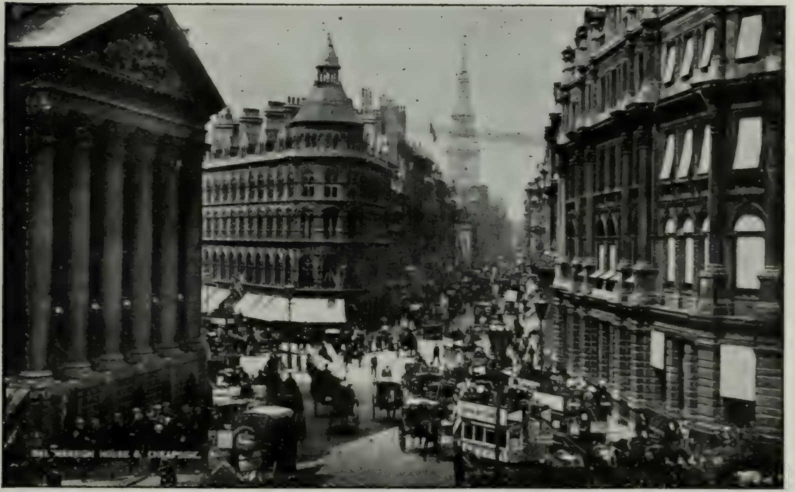
This paper consists merely of the general observations of one who spent two years in continental Europe as an engineer engaged in the examination, construction, and operation of tramways, and who went over the beaten tourist path oblivious to museums, and galleries, and cathedrals, and ruins, with the sordid intention of locating tramway lines in the most hallowed spots of romance and story.

Most visitors to Europe, even those who travel with a Baedeker's guide, or who follow the man from Cook's, have noticed and remarked upon the peculiarities of the European city transportation systems. Unless the visitor is especially interested in transportation methods, however, his attention is chiefly attracted to the multitude of cabs and omnibuses, the funny little cars, the limitation of the number of passengers, the cheapness of the fares, and the frequency with which the conductor comes around for another.

As a matter of fact there is not in the whole of Europe a tramway system which gives anything like the service given by the street railway in the average American city. Berlin comes the nearest to it, but Berlin is the most modern of European cities. The much vaunted municipal tramway system of Glasgow consists of only 100 miles of track. Glasgow is a city of 760,000 inhabitants, and comparing it with American cities of about the same population, St. Louis has 460 miles of track; Boston, 409 miles; and Baltimore, 354 miles. The city of Denver, one-fifth the size of Glasgow, has 142 miles of track. At first thought, the temptation is to ascribe this backwardness in transportation facilities to the natural conservatism of the people, but there are other reasons for the lack of tramway progress.

CITY CONSTRUCTION.

The chief of these reasons is that the location and street constructions of most European cities do not lend themselves readily to tramway building. American cities have been located for commercial reasons, European ones for defensive reasons. One of the attractions in the location of an American city was accessibility; in the European city the very reason for the location was the difficulty of approach. It is interesting to study the locations of some of the smaller towns where the old land-marks have not been obliterated and determine the advantages which led to its selection. It is often a sharp bend in a river which protected the town on three sides, or sometimes a high bluff or hill which facilitated the fortification. In many of the continental towns the old walls are still preserved. In some cases, such as Lille, France, for military reasons; but in many cases, such as Lucerne, Switzerland, for the attraction and amusement of tourists. Now, however picturesque and romantic these locations may be, and however good subjects they may make for painting and poetry, they certainly do not lend themselves readily to modern electric railway construction. Rivers mean bridges, and walls and moats mean cuts and fills, and steep slopes mean rack or incline railways, and all of these innovations are viewed with horror by the city fathers, who dread to see the old order of things disturbed. Most European cities consist of an old and a new city. What corresponds to our retail business district is usually in the old part, while the residences are in the new part. The old part of the cities has narrow, crooked streets and narrow sidewalks or none at all.



The Narrow, Congested Streets of London.

Tramways constructed in these streets must be single track with turn-outs, as usually it is impossible to find a parallel, adjacent street on which the mate for a double track may be built. In some of the European cities, notably Paris, straight, wide boulevards have been cut through the older part of the city, rendering it easy of access. This same process of street making and widening is now being carried out at great expense in London. Berlin and some of the larger German cities have had most of their growth during the last 50 years, and they have straight, wide streets like an American city. An interesting example of the old and the new is Vienna. The older part of the city, about 1 ½ miles in diameter, in which are located most of the retail business houses, hotels, etc., has narrow, crooked streets and no means of transportation except cabs. The walls which once surrounded this city have been demolished and in their place a beautiful boulevard has been constructed. This boulevard is lined with galleries and public buildings, and radiating from this boulevard or ring, as it is called, are wide, straight streets leading into the residence districts. All tramways end at the ring, none of them entering the old city. It can readily be imagined that these tramways do not give the service or offer the accommodation of the American tramway, which takes a man up at his residence and deposits him at his place of business.

The building of tramways on the boulevards and fine streets is usually prohibited, and their construction in the old and congested portions of the cities is often impossible. These facts, combined with the relative cheapness of cab fare and the great number of cabs and omnibuses on the streets, make these methods of travel most popular. In many places it is absolutely impossible to enter or cross the center of the city in a tramway, and rather than lose the time required to go around by a belt line, a passenger whose time is valuable will use a cab. It is needless to say that these conditions rob the tramways of a large portion of the business to which they are entitled, and tend to cut up the tramway system into a number of unconnected, disjointed lines.

CONCESSIONS.

Concessions for the building of tramways are granted under different conditions in the various countries. In England, the conditions as to length of franchise and purchasing power of the municipality are so onerous that enterprises of a private nature are discouraged, and many of the large electric systems which have been built are operated by the municipalities themselves. There are a number of horse roads still in operation which are not converted to electric traction because the proprietors cannot afford to spend the money necessary to make such a change under the conditions imposed by the government. On the continent, long term franchises are freely given on favorable terms, the state reserving the right to purchase the tramway after a certain period of operation. The purchase price is based either on the average net earnings capitalized at 4 per cent to 5 per cent, or is in the form of an annuity, based on the average net earnings, to be paid the railway company during the years remaining in the concession.

The continental countries, as a rule, encourage the building of tramways, sometimes going so far as to subsidize a project until such time as it can be made to pay. Home interests are well taken care of, as it is a common practice to insert in the concession a requirement that wherever possible all material and apparatus to be used in the construction of the tramway shall be manufactured in the country where the concession is granted.

The obtaining of a concession in these continental countries is a long and tedious process in the eyes of one accustomed to American practice. Before any application is made, accurate maps showing the exact locations of tracks, special work, car-houses, etc., must be drawn; all the designs of power plants, cars, etc., must be made; complete time-tables, showing the service to be given, must be studied out. In fact, the proposed construction and operation of the road must be indicated in the greatest detail. Copies of each of these must be submitted to each commune through which the railway is to run, and public meetings to discuss the public utility of the concession are held. If the concession is approved by each commune, or if the railway company agrees to the changes proposed by the communes, the plan as a whole is referred to the department or canton council who must pass upon the project in its entirety. The ruling of the department council in the matter is final, except when the road is in two or more departments, in which case the minister of public works or some federal authority must approve the project.

With all this red tape, the acquisition of a concession is a slow and tedious process. In France, after all the plans are finished, it takes about two years to get the final approval of a concession even when no opposition develops. During these two years the progress in invention may have developed new motors, new systems of transmission, new types of cars, or conditions may have changed so that a new routing of the cars might be justified. But it would be a slow process to get amendments approved, and the road is usually built on the original plan, so that the tramway is often two or three years behind the times when construction is begun. All the agreements between the tramway company and the municipality are drawn up in the form of a contract signed by both parties, and printed in a book form called in France, a "cahier des charges." This contract is very lengthy, prescribing exactly what are the rights and privileges, and what are the duties of the tramway company, and it is but just to the European municipalities to state that although they hold the tramway companies to a strict compliance with the provisions of the agreement, they protect the tramways thoroughly in their rights and do not use the police power to harass them. All conductors and subordinate officials are sworn officers of the law and have all the authority of police; teams are not allowed to follow the track, but only to cross it; disorderly conduct on the cars is punished severely; any interference with the track, signals or apparatus of the tramways is regarded as a penal offense.

TRACK.

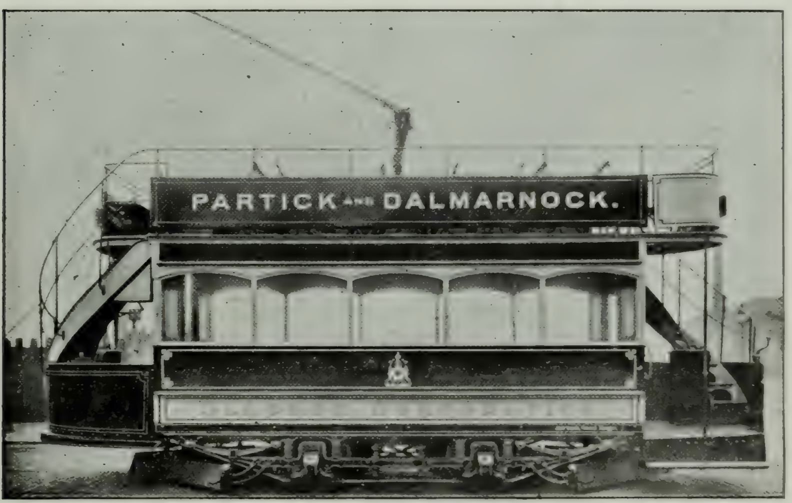
Track in city streets is usually laid directly on concrete beams without the use of wooden ties. Tie rods hold the rails to gauge. The rail mostly in use at present is a section called the Phoenix rail, somewhat similar to our grooved or Trilby type. Various sections have been used. A tee rail with a rolled guard section bolted to it is quite common, while a built-up section called the Marsillon type has been used a great deal; this consists of two tee rails with narrow bases bolted together, the space between the two rails forming the groove. It is needless to state that all these built-up sections soon get loose and shaky and that the groove is very difficult to keep clean. On the suburban roads and in some of the smaller cities, the tee rail laid on wooden ties is used. The joint question has not received the attention it has had in America, because the cars have been lighter, and are operated on much longer intervals. Ordinary fish-plate joints are used, and in some of the latest track laid, 4-hole plates are used on 7-inch rails. A great many cast-welded joints have been made all over the continent, mostly on old rail.

The electric equipment at present installed closely resembles that used in America; in fact, the two large American manufacturers of electrical apparatus are allied to companies in all the European countries, who follow closely the American models. Unfortunately, a number of the engineers who have been in charge of the construction of tramways have thought it necessary to design their own motors and there are a number of small manufacturing concerns who manufacture motors with hand-wound armatures and a commutated field control, a type which has been abandoned in this country for ten years. These motors are sold often because the manufacturers are connected with the financial interests promoting the tramway, or for sentimental reasons because the manufactory is located in the same city or department as the tramway.

The city tracks are usually laid 1.44 meter gauge, which is the same as our standard 4 ft. 8½ in. gauge. The meter gauge has been adopted very largely for suburban railways, because the track takes up less room on the highway. There is no advantage in this, however, and there is a positive disadvantage, as the narrow gauge crowds the motors and brakes on the trucks and prevents the use of standard apparatus.

CARS.

The style of car varies with the different localities. In England, the use of the double-deck car is almost universal. In fact, the car in England is the evolution of the omnibus and looks like an omnibus body mounted on a street car truck. The double-deck car is also largely used in Paris. In London and Paris, the climate is so mild that the deck seats are popular the year round. The usual type of car on the continent is a small box car, 16 or 18 feet length of body, mounted on a single truck. The platforms are small, the roof low, and the cars usually have an awkward, dry goods box appearance. They are cheaply constructed and there is none of the grace in design or elegance in finish to be seen in the products of the American car shops. Quite a number of American cars have been shipped to European cities and are in operation, and these cars are now serving as models for the European builders.



Double-deck Car in Glasgow.

As the cars are usually short, single trucks are almost universal, and the long, double truck, easy riding cars which are now so common in America are to be seen on only a very few of the latest European tramways.

METHODS OF PROPULSION.

The overhead trolley is used everywhere for the propulsion of cars. Wherever possible, in narrow streets, the span wires are fastened by ornamental rosettes directly to buildings and the use of poles is obviated. This vastly improves the appearance of the street. Where poles are used in city streets, the municipality usually insists on their being of an ornamental type. In certain portions of the large cities, the use of the overhead trolley is prohibited and in these places every known method of propelling a car is in use. The open conduit underground system, such as we have in New York, is in use in Paris, Lyons, Brussels, Dresden, Berlin and Vienna. In these cities, however, the conduit is placed underneath one of the rails instead of being between the two rails. The storage battery is used on the cars in Berlin to carry the car past certain places where the overhead trolley is prohibited. It is connected in parallel with the trolley and charges directly from the trolley current. The fumes of the acid fill the car, the depreciation is rapid, and fires from short circuits caused by leaking acid are frequent. In Munich, the only place where the trolley is prohibited is directly in front of the royal palace, and trolley cars are towed by this hallowed spot by means of a storage battery locomotive. The surface contact system is in use at Monte Carlo and in Paris. Its use in Paris has been very unsatisfactory.

Typical Electric Tram-car in Smaller Continental Cities.

Besides the electric systems there are in use steam locomotives, compressed air cars and Serpollet steam motor cars. All of these systems are to be seen in Paris. Most of the narrow gauge suburban tramways are operated by means of small steam locomotives drawing a train of cars. The locomotives resemble the type used on the elevated roads in this country. Sometimes they are boxed in so that their moving parts are hidden. The fuel used is coke and briquettes made of crushed coal, and usually there is a requirement that coke shall be used while in the cities.

It is not unusual to find horse roads still in operation, although most of them have been changed to some form of mechanical traction.

UNDERGROUND AND ELEVATED ROADS.

In a number of the large cities, attempts have been made to atone for the lack of street transportation by underground and elevated roads.

In London a number of years ago several underground roads were built, operated by steam locomotives. These feed into what is called the Circle, which corresponds to the Union Loop, in Chicago, except that the area comprised within it is much larger. More recently other underground roads have been built, operated by electric locomotives, the latest of which, the Central London Railway, gives fairly good service. It is proposed to change the motive power of the steam roads to electricity, so that all parts of this immense city will have rapid transit. The London electric underground roads differ from those in other cities from the fact that they are not built in subways, but in tunnels, sometimes as deep as 80 feet below the surface. This is made possible by the fact that the city of London is underlaid by a deep soft clay, which is easily tunneled.

Paris Tram-car, for 1st and 2nd Class Service.

An elaborate underground system has been planned for Paris, of which six miles have been in operation for two years and a new section is now about to be put in operation. A short portion of this is elevated, but that built underground is built as a subway, constructed in open cut and built as near the surface of the street as possible. The trains are drawn by electric locomotives.

In Berlin a combined underground and elevated road has been recently put in operation, the motive power of which is electricity, and in Vienna there is an elevated road leading to some of the suburban towns, operated by steam locomotives.

In all of these cities where elevated roads are in use, a very pleasant effect is left on the visitor by the ornamental and artistic character of the structure and stations. In this the construction differs radically from American practice.

SERVICE.

Those of us who are engaged in the tramway business in America have come to regard the hours between 7 and 9 in the morning, and between 5 and 7 in the afternoon as the critical periods of the day. We plan our services according to these peaks, and if by 7 o'clock at night nothing has broken down, we breathe a sigh of relief and consider that things are safe for that day. Tramway service in Europe, and especially on the continent, is characterized by a smoothing out or an utter absence of these night and morning peaks. Business begins at varying hours in the morning, and stores keep open until later in the evening than with us. In all of the smaller towns and in the smaller stores of the larger continental cities, it is customary to close the stores between noon and two o'clock for the mid-day meal, and during this time business is entirely suspended. The consequence is that there is a peak at twelve o'clock, followed by a period of stagnation in tramway business until two o'clock, when there is another peak. This is not so noticeable in the larger cities on account of the greater floating population.

Just as the cities were originally laid out without regard to rail transportation, so the large factories and industrial suburbs were established before the advent of the tramway, and the question of the facility of access by workmen was not given much weight. Workmen usually live in the immediate neighborhood of the factories and walk to and from their work. This fact robs the tramways of what in America constitutes one of their best sources of revenue. As a consequence of these conditions tramway service in continental Europe is differently planned from that in American cities. About the same intensity of service is run throughout the entire day. There is an absence of the night and morning trippers, and in their places extra cars are sent out at noon to take care of the mid-day rush. In some of the cities tourist travel is a very productive source of revenue, but the banner days are the pleasant Sundays and fete days, of which there are a great many. No self-respecting citizen in the Latin countries would stay at home on such a day. He takes his family or his sweetheart and goes to the parks, to the cafes, to the restaurants, to the concert gardens, to the country, anywhere so that he goes. Days such as these crowd all transportation agencies to the utmost.

As a general rule, the service given by tramways is poor considered from the American standpoint. The interval between cars is long, a ten-minute headway being considered good service, and the speed is slow, owing to crooked, narrow streets, waits at turnouts, and city regulations limiting the speed. In most of the cities the number of passengers to be carried by each car or omnibus is limited to so many seated passengers, and so many standing passengers, this capacity being determined by the city authorities and painted upon or posted in the car. When this capacity has been reached, the conductor is supposed to hang out the sign "Complet" (or "Full") and refuse to take any more passengers. It is one of the sights of Paris to see the long lines of waiting passengers at the omnibus stations. As the passenger arrives, the station agent hands him a numbered check giving his order in the procession. When the omnibus arrives, the conductor calls off the number of vacant places, the station agent calls out the lowest numbers, their happy possessors enter the omnibus, which then drives off, leaving the remainder to wait for the next omnibus. Regulations limiting the number of passengers exist in all cities, but in some places, passengers have taken the law into their own hands, and crowd into the cars and hang on to the straps in the good old American fashion.

One of the most annoying requirements insisted on in continental countries is the division of the cars into classes, with different rates of fare. This necessitates cutting the car into two sections or running a train consisting of two or more cars instead of a single vehicle. The rate of fare asked in the first-class compartment is usually one-half to one-third more than the second-class compartment, but only a small proportion of the passengers travel first-class and the expense of providing this additional service is not justified by the earnings. This practice of having two classes of passengers, together with that of having certain stations where the cars stop whether signaled or not, has been inherited from European steam railway practice, and is inflicted on the tramways because the federal authorities who supervise the construction and operation of tramways have had their training in steam railway practice and try to make tramway practice as much like it as possible.

In France, Belgium and Italy, there are in the environs of the large cities, and throughout the rural districts, a number of light railways built along the highways and corresponding somewhat to our interurban railways, the construction of which has become so popular in

America. These railways are usually of meter gauge, single track, and the trains consist of first and second-class cars drawn by small steam locomotives. They carry parcel freight and their construction is encouraged by the governments in order to improve the transportation facilities in the rural districts. In many cases these roads are subsidized until such time as their earnings are sufficient to pay operating expenses and interest. Many of these properties, with electricity as a motive power and with an active management, would prove valuable investments, as they serve populous districts and there is no restriction on the carriage of freight. In the dignified, easy-going manner in which they are run, however, with slow-speed steam locomotives, three or four trains per day, uncomfortable cars, long waits at turn-outs, and very little effort to build up the business, only the very best of them are on a paying basis. There is not in all of Europe a counterpart of our modern electric interurban railway with its right of way, elegant cars, high speed and frequent service.

Suburban Service, with Steam Locomotive, St. Etienne, France

The fare register on the continent is not often used. There are usually several rates of fare corresponding to the class and the length of the ride, and the conductor tears out of a book or from a roll a colored numbered slip stating the fare paid and the terminus to which the passenger is entitled to ride. The passenger must keep this slip in his possession as long as he remains on the car, as inspectors mount the cars at frequent intervals and assure themselves that each passenger has a slip and that he has not passed his destination. . The conductor settles his accounts by the number of slips which are missing from his book. As the slips are consecutively numbered, old slips may not be used over again. At first glance, this method looks like an awkward, clumsy system, but on account of the large number of fares in use it is difficult to devise a better one. As long as the passenger will patiently submit to keeping the slip in his hand for the examination of the inspector, it is a good check not only on the honesty of the conductor, but on the accuracy with which he has collected his fares. It is not likely that this system would be tolerated in America by American passengers.

RATES OF FARE.

The rate of fare on European tramways is what to the sociologist and municipal reformer is most alluring. He comes back from a trip abroad, announces that in certain European cities, passengers are carried for two cents, three cents, four cents, and demands in thunderous accents why it is that the tramways in America are allowed to charge such exorbitant rates. The municipal reformer's idea of the cheap fare has probably been derived from a very limited experience with tramway travel, as he very likely did most of his riding in a cab and got his figures out of the guide book. If he had attempted to ride for two cents, he would have found that his two cents carried him for only a very short distance and that the conductor soon came around for another fare, and that by the time he reached his destination he had expended more than he would have paid in an America tramway. It is unfortunate and misleading that writers giving the fares charged in European cities do not also give the distances. It will be found that the rate per mile will average about 1½ cents and sometimes higher. In France, the standard "cahier des charges" under which all tramway concessions are granted, establishes the fare at two cents for the first kilometer and one cent for each succeeding kilometer. This would limit the ride to be had for five cents to two and one-half miles or would make the fare for a ride of five miles, nine cents. On the Chicago City Railway, the length of several of the trunk lines is ten miles, while the longest ride offered for one fare of five cents is about twenty miles. The average ride taken by the passenger is difficult to estimate, but is probably between four and five miles. For this average ride, his fare under European rates would be eight cents instead of five cents.

Beyond the question of cost of transportation, the zone system is an effectual barrier to the growth of the city. The American tramway, with its flat rate of fare to any part of the city, has broken up the tenement districts and transplanted the workmen and those dependent upon him to suburban districts, where ground and rents are cheap, and air and sunlight and health are free. This would never have occured with a zone system, which puts a premium on living in the central part of the city. It is not probable that the tramways will ever do for European cities what they have already done for American cities as long as the zone system is adhered to.

EMPLOYES AND WAGES.

The employes on the continental roads have had a military training and lend themselves readily to the discipline of a railway system. In some of the countries the railway employe, after he has served his two years as a soldier, is exempt from further military service except in case of war, while in other countries the railway companies are required to excuse their employes for about two weeks each year for military instruction. Good men can be obtained for conductors and motormen, and the fine trade-schools furnish material for foremen and petty officials. Socialism is rampant among this class of men, and strikes are not of infrequent occurrence. What impresses the visitor, especially in the smaller places, is the instinctive politeness of the employe. In France the conductor says "merci" ("thanks") when he collects your fare and if you are the fortunate possessor of a pass, he touches his cap. Would that we were able to introduce such habits in America! In some of the cities of Germany it is the custom to tip the conductor with one or

Electric Trolley Car and Trailer, Lyons, France.

two cents in case he notifies you when you have reached your street or performs any similar service.

Wages vary with the locality of the road. In Italy, southern France, and Switzerland, eighty cents per day is paid for motormen and conductors. In northern France and Germany one dollar per day is paid; and in Great Britain, the rate is a little higher. Aid and relief societies, accident insurance, pensions, etc., supported partly by the employes and partly by the company, are common.

FUTURE DEVELOPMENT.

Most of the large cities and towns are equipped with tramways, but a great deal remains to be done in consolidation of management, in weaving the separate and independent roads into a united system, in changing the motive power, in standardizing the equipment, etc. The city systems, however, are usually in the hands of owners who realize their worth, and the great opportunity for new enterprises is in the direction of suburban and interurban railways. There are many cases of existing light steam railways where the introduction of electricity and a little push would make a good property, and there are many cases where new roads could be built and profitably operated. It is best in the continental countries to transact all business in regard to concessions through a local resident, as foreign concessionaires are not favorably regarded although foreign capital is eagerly welcomed.

American engineers and contractors have followed American machinery and methods and many are now engaged in the installation of tramways in Europe. This is especially true in Great Britain. Many roads are now being built entirely with American apparatus, or apparatus modeled after the American types. It is found difficult, however, to operate these roads in the American fashion, on account of what is politely termed the conservatism, but what the builder is more apt to term the stupidity of state and government boards of control. It is such long and tedious work to get an opinion or a method changed, that after several sieges of red tape, the temptation is to let things go as they are. It is to be regretted that American capital is not represented more frequently in European tramways. Most of the properties not locally owned are held by English, Belgian and German capitalists.

In this article the question of power station construction has not been taken up, as European practice does not differ in any essential from the best American practice.

DISCUSSION.

Prof. W. D. Pence I would like to ask what is the method of attaching the rails to the ties in both the concrete and wooden tie; what is the device by which the rail is fastened to the tie?

Mr. McCulloch—When concrete construction is used, the bottom of the rail is simply imbedded in the concrete and tie rods are used to hold the rails together. When the wooden tie is used, lag screws are very common; sometimes they use spikes, but usually lag screws.

Mr. Wander—Do they get the rails sufficiently firm by simply bedding the foot in the concrete support?

Mr. McCulloch—Yes, the rail base is wide, and the concrete surrounds the base and comes up some distance on the web of the rail.

Mr. Finley—How do the municipally controlled lines compare with those owned by private individuals for efficient service?

Mr. McCulloch—I do not know that there is very much difference in the point of service. The question of service is regulated, to a large extent, by the municipality, even when the roads are owned by private individuals. All time tables must be approved by the municipal authorities. Most of the municipally owned roads are either in Great Britain or the smaller towns of Germany. I do not know of a parallel case where the operation could be compared.

Mr. Finley—Glasgow, I believe, is considered in this country as having a very well conducted tramway service.

Mr. McCulloch—There is no reason why the Glasgow street railway should not make money. It is a city of 800,000 inhabitants and they have only 100 miles of track. The service given in Glasgow or any city having municipally controlled tramways does not compare with the service ordinarily given in the average American city.

Mr. Finley—Of course there is hardly a fair comparison between the two, but we can compare the municipally owned lines with the lines owned by private companies.

Mr. McCulloch—I do not think municipally owned roads are any better. Their equipment is not any better and the cars do not run any more frequently. In many cases roads built by the municipalities are equipped with the freak products of local manufactories, while roads built by private capital have bought in the open market and bought more suitable apparatus.

Mr. Edward Murray—How does the area of Glasgow compare with the population?

Mr. McCulloch—It is very compactly built—at least the central part of it.

Mr. Tratman—In England, in getting a franchise for a street railway, they not only have to get permission from the city but also from the general government, and when the franchise is applied for almost the same precedure has to be gone through with as in getting a railway charter. Anybody whose interests are affected can oppose and fight it. The different wards or parishes are represented by their engineers, counsels, lawyers, etc., and are in position to start regular legal proceedings against the establishment of a line in certain streets; these preliminary proceedings may take months.

One of the requirements is in regard to the width of streets. On narrow streets you cannot put a line through unless you can prove to the government that it really must be put there and should be put there. Some of my earlier experience was in London, and in connection with the building of tramways. In one case the engineer with whom I was serving was employed on the side of the opposition to one of the tramway schemes. It was his duty to find out all possible arguments against the construction of that line. The proposed route covered some narrow thoroughfares, and one of the important arguments was the width of the street. I have very unpleasant recollections of being detailed as an assistant to measure the width of the street at every street intersection for two or three miles. It was a busy street, where there was traffic night and day, and though of course we selected hours when there was as little traffic as possible, we had many unpleasant experiences. This measurement had to be done over the whole length of the road. Then the figures were compared to show where the street measured less than the law required, and the figures were marked upon the map. We succeeded in defeating the scheme at that time, but it came up again a few years later and the road is now in operation.

In regard to the construction of tracks, I think as a rule they are a good deal better than the American tracks; a good deal more substantial.

In regard to the rails, there was at first a tendency to use the box girder rail, similar to the old Lewis & Fowler rail in this country. Every engineer had his own special section of track. Of course that made it quite expensive, as every road had to be built according to new plans, etc. On most lines they use rails with grooved heads, the groove being usually much narrower than in this country. Although they have plenty of snow and dirty streets, they do not seem to have much trouble from clogging of the rails. In some cities men who look after the switches have a sort of chisel on the end of the handle of a brush or broom. They walk down the track for half a mile or more, sliding this in the groove; it cuts out long strips of dirt, throwing it out just like a plow. In Southampton the track was of a special design, invented by the engineer under whom I served. The rail was a flangeless T rail, the web or stem fitting into grooved cast iron chairs on the concrete base. Keys or cotters passed through the chair or rail web, and no splice bars were used at joints, but a longer chair. Tie rods held the rails and chairs to gauge.

The underground steam railways of London are like our so-called subway lines, close to the surface. They are operated partly by their own trains, but nearly all the main lines of railway connect with the "underground" and run suburban and local trains into the heart of the city by this route. The electric lines are in deep tunnels, but there is an agitation in favor of the shallow "subway" system for some of the projected new lines.

Mr. H. B. Flemming—How does the concrete construction compare with the wooden tie?

Mr. McCulloch—In most parts of Europe hard wood is very expensive and most of the ties used are "treated" soft wood ties; creosoted wood, or something of that sort. On account of the expense of wooden ties concrete construction is usually used. Cement is cheaper there than it is with us, and wood is a good deal more expensive. The climate, too, is somewhat better on street construction.

Mr. Finley—What is the general tendency in Paris now?

Mr. McCulloch—Quite a good deal of trolley construction has been used in Paris, but in the central or show portion of the city, overhead wires are prohibited. The underground electric systems are of two types, one an open conduit system somewhat similar to what we have in New York, and another a surface contact system.

In the open conduit system the conduit is about two feet deep and is placed underneath one of the rails instead of in the center of the track as is common with us. This is done because the authorities object to the installation of the additional slot rail required for the central conduit. It is not as good a construction as the central conduit, and at cross-overs and turn-outs it is necessary to bring the conduit to the center to avoid switch complications.

In the surface contact system, a number of closed boxes with the top or "button" projecting through the paving are placed midway between the rails about ten or twelve feet apart. The tops of these boxes are normally dead but may be connected to a feeder in the bottom of the box by a plunger floating in mercury. A small storage battery on the car attracts the plunger to contact with the top of the box and holds it in this position as long as the car is over the button. The button is then in connection with the feeder and current for the operation of the car is taken by means of a shoe sliding on the buttons. When the car passes on the plunger is supposed to drop back into the mercury and leave the button dead. There are about sixty miles of this construction, but its operation has been very unsatisfactory. Permission has been obtained to operate part of it by trolley while changes are being made.

Mr. Warder—In regard to the conduit placed underneath the rail, what is the method of getting electric energy from it?

Mr. McCulloch—The conduit is placed directly underneath one of the running rails. This rail is a double rail carried on cast iron yokes, and is formed of sections similar to tee rails with the inside bases cut off forming the slot between them. The wheel flange runs in this slot and the conduit carries one-half the weight of the car. A plow is let down through this slot and makes contact with two underground insulated conductors. The slot is very wide. On the drawings it is marked one and three-eighths inches in width, but it is sometimes two inches. In this country the usual width is seven-eighth inch.

Mr. Bernhard—What is the general type of pavement in European cities?

Mr. McCulloch—They have a good deal of asphalt and also a good deal of wooden block pavement. Granite is used only where there is heavy teaming. Pretty nearly all of the driving streets are paved with wooden blocks. They are of very hard wood and good care is taken of them. If the slightest depression occurs the blocks are pulled up and the street resurfaced. The streets are also kept very clean. In bad weather they sprinkle sharp sand over the pavement. They use a good deal of granite in northern France, and some of the highways are paved half with granite and half with macadam. They have very strict laws regarding the regulation of teaming, and the spilling of dirt on the streets and highways. It is an object lesson on the advantage of good roads to see the heavy loads drawn by single horses on the country roads.

Mr. Tratman—I would like to ask if Mr. McCulloch can tell us anything definite about the danger of the surface-contact system in Paris. In *The Engineer* (London) a few weeks ago it was stated that the company using this system (the Diatto system) has abandoned it. It was much more expensive than had been anticipated, and had caused fatal accidents to a great many horses. The company was also continually worried by the city authorities in regard to the danger of the system in crowded streets. It has been allowed to use overhead wires during the construction of the Metropolitan underground railway, and will probably finally adopt the conduit system.

Mr. McCulloch—I have never heard of a man being killed by it, but they have killed horses which have stepped on live buttons or which have stepped in water in contact with live buttons. Sometimes in rainy weather the water will stand in pools along the track for quite a distance and connecting several of the buttons. Street water is a good conductor on account of the impurities which it contains in solution. When a car runs in a pool and energizes a button, all of the water is charged, and if a horse steps in it he is knocked down. The first winter they operated that line they had a little snow and salt was used to melt the snow; the melting of the snow made pools of salt water along the track and several horses were killed. This system is not only unsatisfactory on that account but on account of the frequency with which buttons fail to work, in which case a car is left standing in the street without current and must be pushed by hand to a live button.

Mr. Warder—Referring to the point that Glasgow has a population of about 800,000 and 100 miles of track—have you anything to show about the number of people carried per mile of track? There are some interesting tables of different cities, showing how many people were carried per mile of track.

Mr. McCulloch—The report of the Glasgow Corporation Tramway for the year ending May 31, 1902, states that there were 103 miles of track and 163,678,190 passengers, or 1,590,000 per mile of track per annum.

Mr. Finley—Is our late fellow-townsman, Mr. Yerkes, building underground or surface roads in London?

Mr. McCulloch—Underground altogether.

Mr. Finley—Apparently it does not take as long to get the right there to build underground roads as it does to build surface roads.

Mr. McCulloch—He started in by purchasing some underground steam roads with the idea of changing the motive power to electricity, and at the same time applied for the right to extend these lines. He also bought up some concessions which had already been granted, but which had not yet been financed.

Mr. Tratman—It usually takes much longer to get the right to build railways or underground railways than tramways. The parliamentary proceedings are practically the same, but there are generally many more opponents to the railways, and these cases therefore take more time.

Prof. Pence—Is not the question of ventilation of the underground electric railways in London an important matter in relation to the subways?

Mr. McCulloch—I do not think anything was done in the original construction toward ventilation. The cars fit the tunnel very closely and it was thought that the moving cars would ventilate the tunnel, but there have been a good many complaints about bad air in the tunnel. A commission has been appointed to examine into the matter and they have made some recommendations as to what should be done, but I do not think anything has been done yet.

Mr. Murray—Is not the tendency to adopt American systems in Europe on the increase?

Mr. McCulloch—I think it is.

Mr. Bernhard—I would like to ask if there are any roads installed with alternating current electric motors?

Mr. McCulloch—There is a small road in Switzerland which has operated as a three-phase road for several years. It is an interurban road, and a good deal of three-phase work is being done in the neighborhood of Milan in Italy. I think they have some lines in operation now. The motors themselves run by three-phase alternating current.

Mr. Murray—Is the drainage of the conduits in the surface contact system much of a charge?

Mr. McCulloch—In the surface contact system there is no necessity for sub-drainage, because the box which contains the buttons is entirely imbedded in the pavement and is not open.

THE AWARD OF THE OCTAVE CHANUTE MEDALS FOR 1902.

The committee appointed to award the Octave Chanute medals for the best papers presented before the Western Society of Engineers by members thereof during the year 1902, have carefully considered the several papers, and have reported the result of their deliberations as follows:

June 1, 1903.

Mr. Ralph Modjeski, President Western Society of Engineers, Chicago:

Dear Sir—The undersigned committee of the Society for awarding the Octave Chanute prizes for the best papers read by members of the Society during the year 1902 in civil, mechanical and electrical engineering, respectfully make the following awards;

In Civil Engineering, Mr. John W. Alvord, for his paper on "Sewage Purification Plants."

In Mechanical Engineering, Mr. Robert E Milligan, for his paper on "Mechanical Filtration."

In Electrical Engineering Mr. E. B. Ellicott, for his paper on "The Transmission of Fire Alarms."

Submitting the above, we remain,

Yours truly,
(Signed) L. E. Cooley,
Robert W. Hunt,
Onward Bates,
Committee.

The Board of Direction, at their meeting held June 2, 1903, accepted this report of the Committee, and at a regular meeting of the Western Society of Engineers held June 3, 1903, announcement was made of the award of medals for 1902, according to the above report. J. H. Warder, Secretary.

CLXXV.

HYDRAULIC DEVELOPMENTS AS RELATED TO ELECTRIC INSTALLATIONS.

By Wm. B. Jackson, M. W. S. E.

Presented March 4, 1903.

We are all beginning to appreciate to a greater or less extent the great value of the many waterfalls scattered throughout our land, not only as related to the region immediately surrounding them but also to the country at large. In this day of engineering progress when we pass a beautiful waterfall, although our first thought may be to view it from the artistic standpoint as being one of the greatest beauties of nature, we quickly pass to the economic side and figure in our minds how many tons of coal the harnessing of the stream will save annually, and thus put off the day when our magnificent coal fields will have become exhausted. It is well that we should have a full appreciation of the many beauties to be found along our rivers and at the same time have an appreciation of the power which is each year running to waste in these same streams. However, when considering the matter from the standpoint of the engineer, it is well for us also to fully understand the true limitations of these powers, and the means, that may be adopted with our present opportunities, for turning to our use the greatest percentage of the power there represented.

Perhaps our foremost thought when the matter is considered from this standpoint is what minimum flow must we expect, as this is almost always one of the determining quantities as to the value of the stream and it is most readily appreciated. When it is proposed to utilize the power from a stream in driving a mill it is frequently possible to largely disregard this item of minimum flow, even where the river is to be fully developed, for in some cases such an arrangement may be made that a certain portion of the output of the mill can all be taken care of during the larger flow, this section being shut down during low water without serious loss. Such is seldom the case, however, when considering the development of water powers for driving electric generators, the output of which is to be used for general commercial purposes, for here the minimum water power is of prime importance. The 365-day power is the cream and all other power developed must be considered as a valuable by-product only. Under ordinary commercial conditions the minimum output of the stream is the measure of the amount of steam plant that may be displaced, and the other power developed simply represents coal saved without further advantage.

Although the minimum flow will usually be the first to attract our attention, we must not lose sight of that much overlooked condition of high water, as regards the loss in head occasioned by the backing up of the water, and as regards its capacity for doing almost untold damage during periods of freshets and great floods.

Most of our powers in the East of large importance as regards size are troubled greatly on account of the cutting down in head during high water conditions, and it is this aspect of the case that should usually give the engineer the greatest food for thought. Notwithstanding this fact many of our engineers have not yet arrived at even a half appreciation of this condition. So far as the engineering difficulties to be encountered in the construction of the dam, power house, etc., are concerned, the minimum flow of the river has little effect.

When considered in its relation to the commercial aspect, however, the minimum flow has a paramount importance, for as before stated, it must determine the amount of steam plant actually displaced; and the minimum flow, together with the distribution of flow throughout the year, the cost per unit of hydraulic installation and the cost per unit for its operation, the cost per unit of steam installation and the cost per unit of operating the steam plant must be the factors used in determining the extent to which the stream shall be developed.

It must be always remembered that the actual minimum flow of the river bears the same relation (not ratio) to steam plant that can be displaced whether the stream is being utilized with simply a diverting dam or with reservoir dam (so far as actual K. W. Hrs. are concerned), provided, as is so often the case, the reservoir dam is of such capacity that it is drawn down to its limit each day. A limited reservoir of this character derives its particular value through permitting the use of the water according to the momentary needs of the service, so that the service is circumscribed only by the actual total quantity of water and not by the flow at each instant.

Considering that it is usually advisable to develop streams to a considerably greater amount than the low flow alone would warrant and to install an auxiliary steam plant to be used for from one to six months of the year and sometimes longer, a material saving may be effected in the amount of steam plant to be installed, if the latter is operated continuously during low water periods carrying a fairly constant load of such an amount that the greatest practicable amount of the power from the water may be used during the peak load. Such an arrangement, of course, calls for a plant with a reservoir with reasonable storage capacity. Thus suppose the minimum output of a plant during the day is 200 K. W. and during the peak this runs up to 800 K. W. The minimum continuous output will consume 4,800 K. W. H. per day, and suppose the power above the 200 K. W. limit consumes 4,000 K. W. H. If there is sufficient water and reservoir capacity to develop a short period load of 4,000 K. W. H., the steam plant need only be capable of developing a maximum of 200 K. W. and on account of the development for higher water the hydraulic department will stand ready to do its work at any time. If, however, the water power is distributed throughout the day, giving continuously 166⅔ K. W. (no storage reservoir being provided, or its advantages not being utilized), then the steam plant must be capable of supplying during the peak 634 K. W. thus increasing the necessary capacity of the auxiliary steam plant over three fold. Thus is seen how the manipulation of the relative use of the water and steam plants may affect the necessary capacity of the latter.

Reservoir capacity that is sufficient to hold over during dry periods has of necessity great value as it artificially increases the minimum daily output that may be had from the stream. The factors that determine the advisability of building such distributing reservoirs are: interest on the investment, a fair depreciation, and cost of operating; which must be conjointly less than the actual net returns produced. It is always well to remember that a balance in these factors should decide against the reservoir, as every added feature without positive gain is a detriment, since it introduces a non-productive complication.

The question of minimum flow is especially interesting on account of its uncertain characteristics, and it is interesting to note the diversity of opinion amongst recognized engineers as to what constitutes the minimum flow of many of our well known rivers. Take for example the Potomac River or the Susquehanna River, where the diversity of opinion is very marked. Upon the latter stream this diversity amounts to as much as 100 per cent. It might be remarked that the lower estimates are usually more nearly correct.

It is well known that the rainfall upon the drainage area has much to do with the flow of the river but a satisfactory rule for determining the exact inter-relation has yet to be found. In general in New England, where a rainfall occurs of from 30 to 38 inches, a minimum flow of about 0.2 cubic feet sec. per square mile of drainage area can be relied upon for most of the years; while in North and South Carolina, where from 48 to 56 inches of rain are usual, something like 0.5 cubic feet sec. per square mile of drainage area may be expected. In central Michigan, on one river I know well, about 0.37 cubic feet sec. per square mile is seldom lowered. But such flows cannot be relied upon with absolute certainty, for once in long cycles, and some times for two or more years successively, the flows of the rivers will be phenomenally low. However, in figuring upon the development of a stream for power purposes the absolute minimum should not be taken as the continuous flow of the river, but a practical minimum should be decided upon such as, for instance, can be absolutely relied upon in ten years out of eleven. The lower flow that might occur once in ten to twenty years should not be considered as greatly diminishing the value of the river as a power producer. In some streams the dams already constructed above the proposed development oft times have more troublesome tendencies than the minimum flow from the water shed, for the latter never ceases entirely in normal streams, while the former may stop the flow completely for intervals. Thus the question of storage capacity in the pond is raised to paramount importance. This is well exemplified in a small hydro-electric plant that I operated some years ago.

When all of the mills above on the river were shut down on Saturday night, each reservoir would, one after the other, have to fill up before any water would reach my reservoir. Thus at times my plant was almost shut down, when I knew that the river was passing at some point, far or near, according to the condition of the upper reservoirs, at least 220 cubic feet sec. of water.

From what has gone before, is seen the necessity of considering with great care the actual conditions of flow, whether natural or artificially controlled, to be expected from a river, before deciding upon the mode and the extent of the development.

Here then is encountered a very pretty problem for solution which must be solved in each case, with the amount and charactor of the load, cost and depreciation per unit of development (with its cost of operation), minimum and distributed flow of the stream and the storage capacity available, together with the cost per unit of steam plant with its cost of operation, as the determining quantities.

Although, as is seen, the minimum flow has a far-reaching influence from the larger engineering standpoint, that is, from the economic point view, the high water condition has a paramount influence from the abstract engineering standpoint on account of the two conditions earlier enumerated.

The matter of so designing the structures as to withstand the onslaughts of the tremendous floods, carrying with them, as they do at times, great masses of ice, drift wood and sometimes even boulders, is no mean undertaking even in the least turbulent of streams and it becomes a great art in most of our best power producing rivers. However, except in unusual cases, the work that is to be here done has to do with stresses and strains which may be calculated to a fair degree of accuracy, so that there is little excuse for the washing out of dams, power houses and such like unless the flood occurs during the construction of the works.

A great menace to the solidity of a properly designed dam is poor workmanship. It is exceptionally easy for a mistake to be made in a large structure which may be covered in and show no outward sign, until at a crucial moment the fault may be uncovered at terrible cost. Nothing but unceasing vigilance on the part of thoroughly honest, trained men during the construction of hydraulic installations can prevent such possibilities; and until such is fully appreciated, we will continue to have the disastrous results that are now so common during great floods. The perfect design of a dam cannot obviate the possibilities of washout when confronted by poor workmanship.

The strength of a properly designed and constructed dam to withstand the forces that will be thrown against it should be just as assured as it is with the sky scraper buildings that surround us.

The feature in high water conditions, however, that probably appeals to the interest of the thoughtful engineer more than any other, is the possible variation in head occasioned by the backing up of the water in the tail race. In many powers, which even now have considerable commercial value, the head actually disappears during very high water periods Usually these powers have been developed many years ago when the production of power was in a very different stage of development than it now is, and they retain their commercial value largely on account of being already established. A good example of such a power is to be found in the city of Grand Rapids, Michigan, on the Grand River.

If we consider as a premise that the operating head may be cut down to two-thirds normal during very high water, without seriously interfering with the operation of the plant and without necessitating any special hydraulic construction further than a large capacity during normal flow periods, to give satisfactory results, there will be found many otherwise valuable powers that are seriously crippled at high water periods unless special provisions are maintained. A large number of fine water powers will be found that at times will have the head seriously reduced and sometimes to almost nothing during high water periods if no special construction of dam and head works is arranged for and yet which are too valuable to be allowed to remain undeveloped. There are also many powers in which the head is at times seriously reduced but wherein the reduction cannot be sufficiently lessened by any such special construction so that large variations in head must be taken care of through the construction or arrangement of the water wheels or both. The former condition is an exceptionally prevalent one and in many cases its only remedy is to construct the width of overflow of the dam so that for every foot rise in the tail water a suitably graduated increase occurs in the depth of the water passing over the dam so as to maintain a reasonable head on the wheels. This may sometimes be supplemented by the installation of extra wheels for use during high water periods, in combination with specially designed turbines for good operation under varying heads.

A fine example of such a construction is shown at the Rock Hill development of the Catawba Power Co., in South Carolina. The normal head here is 25 feet and at times there is a rise of 22 feet in the tail water. To offset this, the dam is so constructed as to give a rise at the dam crest of two feet for each three-feet rise in tail water. Such an arrangement gives at periods of 22 feet of back water, a working head of 17⅔ feet. To maintain the speed and give sufficient power under these conditions, extra wheels are installed for use at such times and the regular wheels are designed with special reference to service under varying heads.

Where it is requisite in a development to construct a canal to carry the water from the reservoir to the power house it is readily appreciated that the canal bank must be of sufficient height and strength to withstand the increased depth of water at high water.

When equalization of head is desired by greatly raising the level of the water in the reservoirs at times of high water, it is seen that the cost of construction may make the scheme impracticable, also that the necessary flowage rights may become a serious and costly matter. This latter factor is sometimes not given due weight.

In some power developments the raising of the reservoir level is impracticable and here some arrangement must be evolved whereby the water wheels themselves (or their arrangement) will give satisfactory results under the varying heads.

For small units this appears to be solved to a fair degree of satisfaction at Portland, Oregon, by the use of vertical wheels in pairs of two, one to be used when the head is normal, the other when it is cut down by back water. The generator is carried upon the shaft of the high head wheel and a belted cross connection may be made between the shafts of the two wheels. Such an arrangement is, however, out of the question where large units are under consideration.

The conditions at the Great Falls of the Potomac River near Washington present a fine example of what may be encountered as regards variation of head. Here during the normal flow of the river an 80-foot head is obtained, but during the high water conditions this head is sometimes cut down to less than half of normal, while at the time of the Johnstown flood when the Eastern rivers were very high the head almost entirely disappeared. It is possible here, without serious difficulty, to get 10 feet additional head during high water through the rise in the reservoir level. Thus, barring very

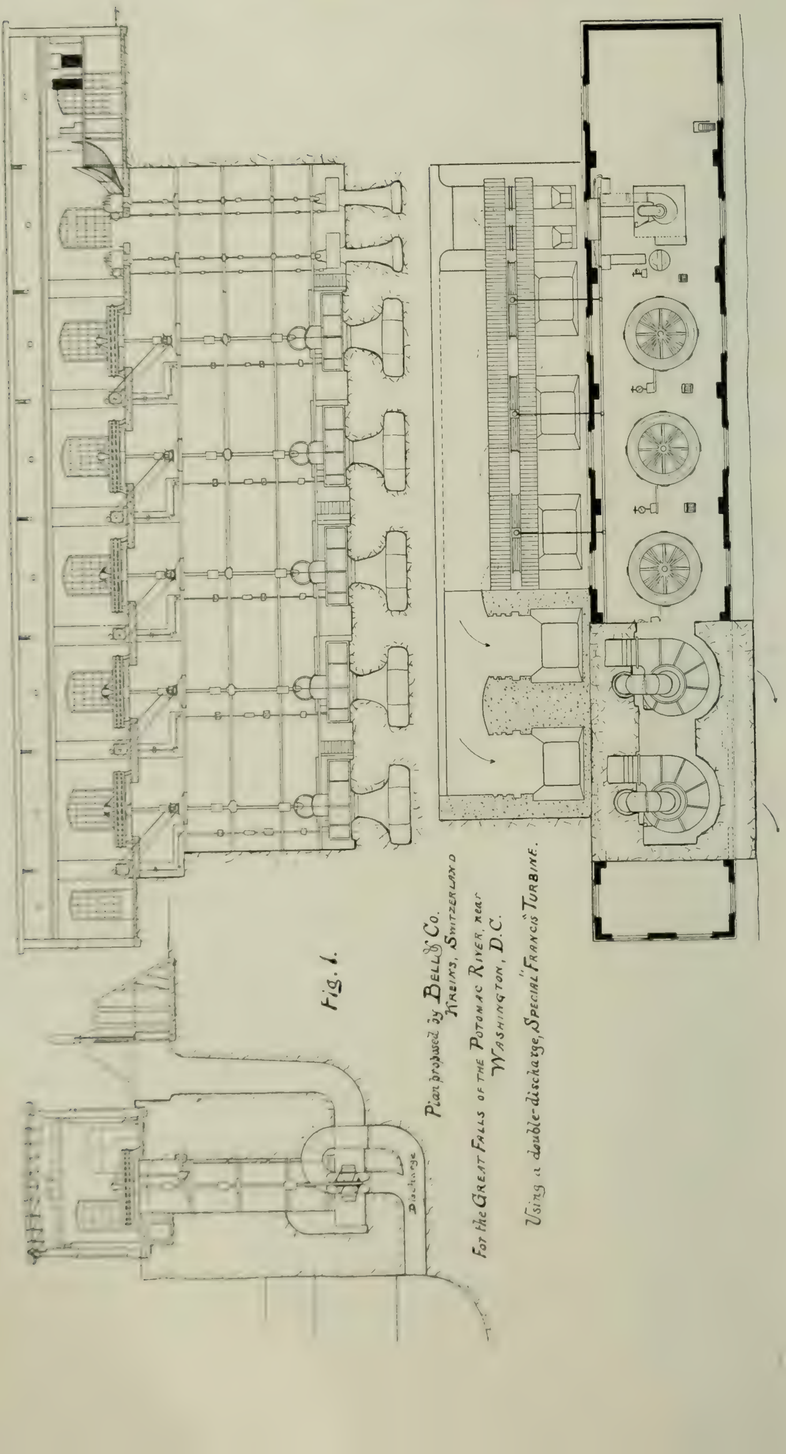


Fig. 1.

Plan proposed by Bell & Co.
Kreins, Switzerland

For the Great Falls of the Potomac River, near
Washington, D.C.

Using a double-discharge, Special "Francis" Turbine.

exceptional cases, a head of 40 feet or more may always be relied upon. The efficient development of the low flow of the river is essential, though of course, efficiency has no importance when there is troublesome back water, because of the great volume of water passing.

Bell & Company, of Kriens, Switzerland, propose to overcome the difficulty introduced by the variable head by the use of a carefully constructed wheel of 350 R. P. M. having an output of 3,500 H. P. at 80-foot head and 2,500 H. P. at 40-foot head. The plan as drawn up by them is shown in Figure No. 1. They propose to use a specially designed Francis type of turbine discharging both upward and downward with guaranteed efficiencies of 80 per cent at full load, 84 per cent at ⅔ load and 76 per cent at ⅓ load.

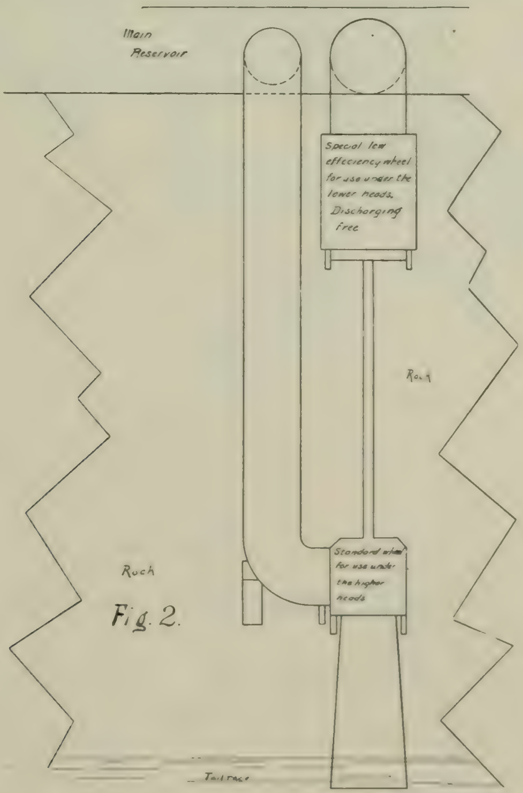

Main Reservoir
Special low efficiency wheel for use under the lower heads. Discharging free
Rock
Standard wheel for use under the higher heads
Rock
Tailrace

Fig. 2.

Another method that has been proposed is shown in Figure No. 2 wherein standard wheels are used under the higher heads but on each shaft, detachable by sleeve and clutch, is a wheel to operate at the required speed at much lower heads and using water without regard to efficiency. It has also been proposed to have two distinct plants, one to operate at the higher heads (using direct-connected electric generators) and the other, with slow speed wheels and belted electric machines, to operate when the head is cut down.

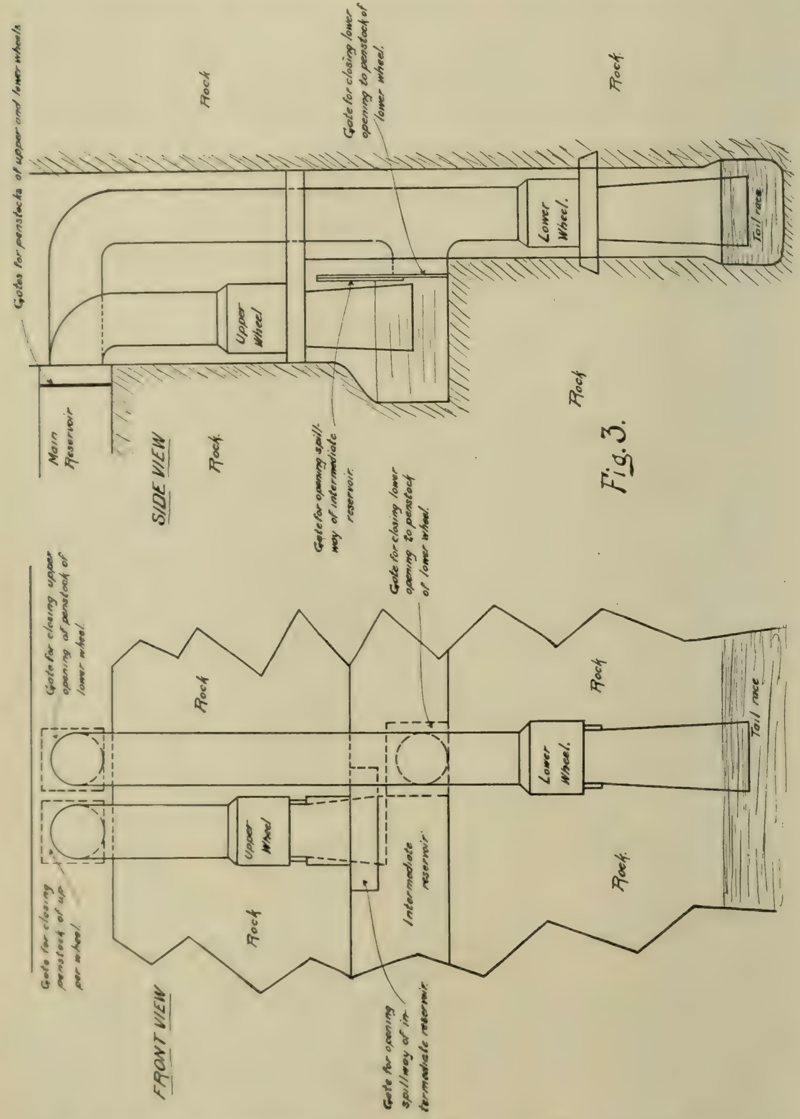

Gates for penstocks of upper and lower wheels
Rock
Gate for closing lower opening to penstock of lower wheel.
Rock
Lower Wheel.
Tail race
Upper Wheel
Main Reservoir
SIDE VIEW
Rock
Gate for opening spillway of intermediate reservoir.
Gate for closing lower opening to penstock of lower wheel.
Rock
Gate for closing upper opening of penstock of lower wheel.
Rock
Rock
Tail race
Lower Wheel.
Upper Wheel
Intermediate reservoir
Rock
Rock
Gate for closing penstock of upper wheel
FRONT VIEW
Gate for opening spillway of intermediate reservoir

Fig. 3.

The writer has suggested a method as shown in Figure No. 3 wherein the wheels are set at two levels and operate in something of a series-parallel arrangement.

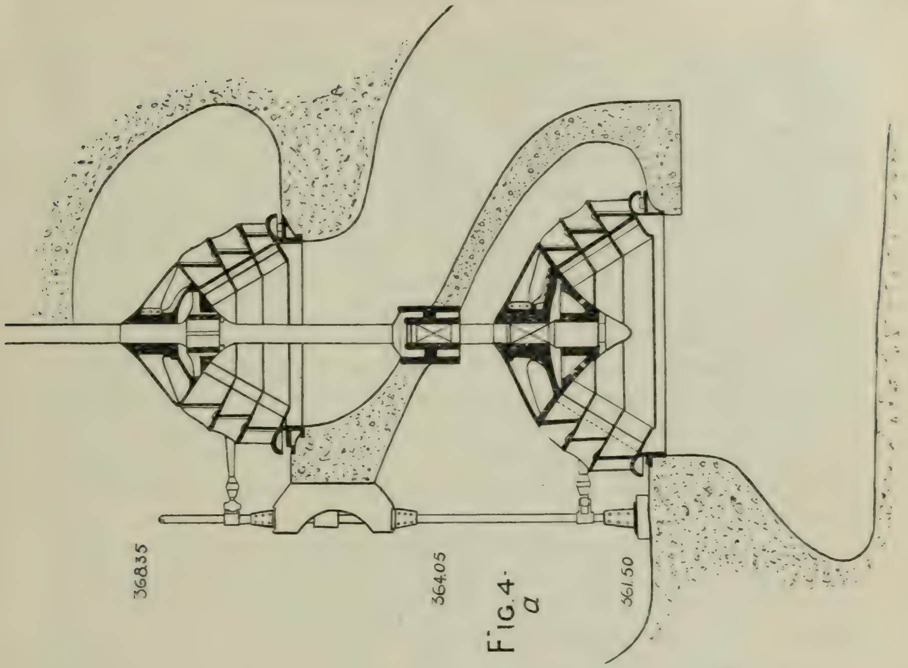


Fig. 4 a

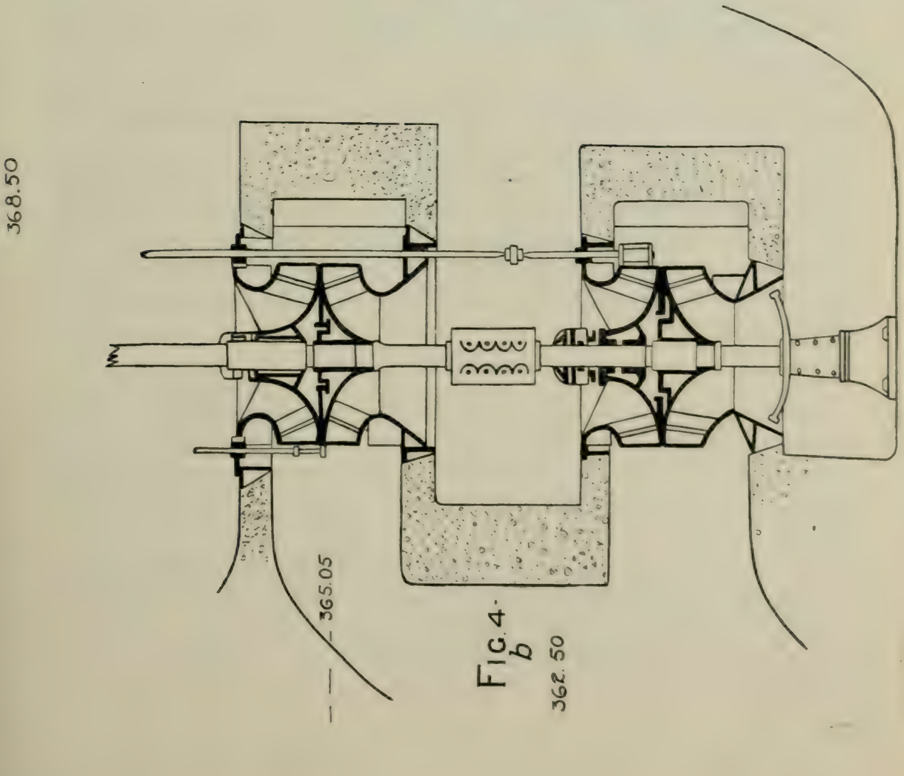


Fig. 4 b

During the higher heads the upper set of wheels discharge into an intermediate receiver from which the lower wheels take the water. Thus the two sets are working each under a head of 40 feet and may be said to be in series. When the rise in the tail water cuts down the head of the lower wheels to such a degres as to interfere with their satisfactory operation, the penstocks of the lower wheels are cut off from the intermediate reservoir and are connected to the main reservoir. Gates are then opened in the intermediate reservoir to permit the discharge from the upper wheels to spill directly into the tail race. Until the water rises greatly, the lower wheels must then work under abnormally great head and must be operated with throttled gates, but under all con ditions both the upper and lower wheels have full head until the back water has risen over 50 feet. When the back water has risen just 50 feet and the head water 10 feet, all wheels will be working under exactly normal head, the one set on draft tubes the other set submerged.

At Geneva, Switzerland, the great changes in head have been taken care of by having two wheels threaded upon each shaft as shown in Figure 4 in which the lower wheel is used alone during the higher heads and will produce 1,200 H. P., while at the lowest head the two wheels working together will produce 800 H. P. at normal speed. The head here varies from 28 feet to 14 feet (8.5 meters to 4.3 meters).

The wheels as shown in sketch "a" are designed for 80 R. P. M., with inward discharge, while those in sketch "b" are designed for 120 R. P. M., with outward discharge.

In conclusion it may be said that there are but few water falls which may not be satisfactorily developed for high water conditions, by taking advantage of the increase in head that may be produced by the proper design of the dam and head waters, in combination with specially designed and installed wheels for operation under varying heads.

DISCUSSION.

Mr. T. T. Johnston — Mr. Jackson has stated quite clearly many of the elements that will be met in the development of a water power, especially in its application to water-driven electric power plants. It rarely happens that any two developments present like problems at the water end. The diversity of the elements seems to be infinite. The electrical end is usually comparatively plain sailing, the diversity of problems appearing rather in details than in essential general elements. It is usually some element in the water end that fixes the size of units and speeds, which are the salient elements in the electrical end.

The hydraulic engineer must ordinarily invent a new conception for the development of the water power. He has no beaten path to follow and the opportunity for a fatal or expensive error is ever present. He must fashion it to meet the requirements of known electrical apparatus, in which he must be, in general, at least acquainted. He can rest assured that the makers of electrical goods will go but little out of their way, because they can not, to fit the requirements of the water-power.

Mr. Jackson refers quite pertinently to the "economic side" of a water-driven electric plant. Strictly speaking, this is not an engineering question — at least, not in a constructive sense. Nevertheless, the designing engineer is called upon frequently, if not generally, to pass on the economic merits of a proposition, and to do this he should know something of "financing," just as the hydraulic engineer must know something of the general elements of electricity. The writer's experience has run somewhat along these lines, not only in designing and reporting on water-driven electric plants, but also to expert evaluation of other industries, such as water works, etc.; it may not be amiss to discuss this branch of the subject a little more at length. The commercial or economic merits of a power proposition, or a water works or any other public, semi-public, or private industry may be made to turn upon a consideration of proper annual charges. The fundamental consideration is that the capital invested must suffer no loss, and must ultimately be restored in the shape of money, or an equivalent therefor. Capital invested by no means refers simply to the cash invested. It is the cash invested plus such accretions as may be properly added by failure of the proposition to yield at all times an interest on the cash investment, plus a deficiency in proper profits, plus expenditures in any accounts which are not provided for and realized from annual revenues. Assuming a case in which interest and revenues are figured on an annual basis, the salient elements entering annual charges may be stated as follows:

(1) Interest on Capital Invested.
(2) Maintenance and Depreciation.
(3) Operating Expenses.
(4) Lost Revenues.
(5) Going Concern Charges.
(6) Taxes.
(7) Sinking Fund.
(8) Miscellaneous and Contingent.

Each of these items may be discussed briefly and individually.

(1) Interest on Capital Invested.

Capital invested includes the actual cash put into the enterprise, also the interest on this cash during the period of construction and up to the time it became revenue producing; also, the cash equivalent of services rendered in organization and otherwise, during the period of construction, which are permanently revenue producing.

It may also be made to include the cash equivalent of property on hand, such as riparian rights, real estate, old installation, etc., but it is not so considered herein, as that is to be taken up under item (4) or Lost Revenues.

(2) Maintenance and Depreciation.

Annual charges for Maintenance and Depreciation refer to those annual expenses for maintenance and also to such sums as should be annually set aside, on account of depreciation, all having in view the keeping up of the property in a condition as good as new, so that its value may remain unchanged.

(3) Operating Expenses.

Operating expenses are those annual expenditures which produce no physical results which will be permanently revenue producing.

(4) Lost Revenues.

Lost revenues are those which might otherwise be derived from realty and riparian rights, by leasing them. They represent the interest in the capital value of such property, and as before said, might properly be included in interest and investment; but as they play an important part in determining going concern charges, they have been taken up separately.

(5) Going Concern Charges.

It frequently happens, just as during the period of construction, so for some time after that period, the plant will in part be idle, and non-revenue producing, and interest will be accumulating. This feature of the commercial merits of an industrial plant assumes many phases, and is often quite difficult of determination, especially after the plant has been in operation for some years, because the book-keeping has not usually been arranged for such a determination. It is sometimes stated that a developed business is more valuable than one that is undeveloped, and that this value constitutes going concern value. The writer will not go into this complicated branch of the subject any further, at this time, but will make only this brief reference to it.

(6) Taxes.

Taxes, we all know, must be paid, and are frequently a formidable item in annual charges.

(7) Sinking Fund.

The term "Sinking Fund," is not here used in the sense of providing for the cancellation of indebtedness. It has another and very important meaning, and is applicable in a greater or less degree according to the case in hand.

It sometimes and even frequently occurs that even after a maintenance and depreciation charge has been provided to keep the plant at all times as good as new, nevertheless, after a certain period of time the plant will become useless for some reason or other. For instance, some new and much better apparatus may come into use, doing the same work more cheaply, and necessitating the partial or complete abandonment of the old plant. Such an event transpired in the case of two large water supply plants designed and built by the writer. At Memphis, artesian water of superior quality was discovered and the old plant for furnishing inferior river water had to be abandoned. At Savannah, an old artesian plant had to be abandoned because its arrangement made extensions impracticable. At Joliet, the old water-driven electric plant had to be abandoned when drainage canal water allowed us to install an improved development. Provision should be made for an annual charge for such a contingency, and be called a sinking fund.

(8) Miscellaneous.

Miscellaneous charges properly refers to the operating expenses which can not be anticipated, and for which no provision may be made in current revenues. Damage suits, extraordinary legal expenses, accidents to plant and items of such nature are included. Some sort of a guess as to their magnitude should be made in annual charges for operating expenses, or else the items should be added to capital account, and pay interest until the capital invested is returned to the investor. The writer has dwelt somewhat on these items because it seems to him that they have been too frequently ignored and with disastrous failures as a consequence. The great power plant at Massena is a startling example of commercial failure and loss to original investors. Niagara came nearly to the same end. No one yet knows what will happen to the Sault Ste. Marie. It seems also, to the writer, that the proposed developments of water-driven electricity at Lockport by the Sanitary District have not been fully considered in this light. So many commercial failures have had existence that it might seem wise to consider these projects carefully in a commercial as well as an engineering way.

The first question on the economic side, after figuring the matter, is: Can the annual revenues be made to exceed the annual charges enough to provide a profit? The second question is: Can not the same result be reached better and more cheaply in some other way — as by use of steam instead of water power? It sometimes happens that it can be, if the cost of hydraulic installation is large.

The writer is inclined to take issue with Mr. Jackson in the statement that "poor workmanship" is the greatest menace the engineer meets in the building of a dam. The writer has built a number of them and his experience is that the matter of "poor design" has given him more worry than has "poor workmanship."

The ordinary methods of calculating the stability of a dam are exceedingly unsatisfactory, because illogical and empirical and of a very variable character, with no assurance that there is taken into account all the elements affecting stability. In fact, it is known that they do not.

In one case the writer had to build a dam in the Snoqualime river in Washington, at a place where the high water velocity was 25 feet per second or about 18 miles per hour. Rise of river, 15 feet. He must make a low water pool to get water in an intake for the power plant. He must also arrange that high water elevation should not be much higher. In another case he had to build a dam across the Snake river in Idaho, one section 500 feet long and 12 feet high, the other 550 feet long and 35 feet high. Low water head 4 feet and high water head nothing. He had to make a low water head of 18 feet and so dimension the length of crest of dam that the high water head would be the same. Normal rise and fall of river, about 15 feet. The dam 35 feet high was made of concrete, no part of which was more than 5 feet thick. A front wall was made 5 feet thick, backed every 20 feet by buttresses 5 feet thick and 20 feet deep, in the direction of the river.

In another case - the dam at Jackson street in Joliet, was designed so that the tail water in the river bed would oscillate in harmony with the head water so the "head" would be essentially constant. Other cases, built and in hand, present equally unique features.

The conception of the arrangement of the dam, its disposition, materials of construction and design in general, are the most troublesome elements.

Mr. Jackson makes some reference to the relation between low water flow and rain fall. The writer believes this to be a relation that is practically indeterminate. He has observed the Des Plaines river with 700 square miles drainage area and with no water at all flowing. The Kankakee (from a marsh bed) has a low water flow of about ⅛ cubic foot per square mile. Many tributaries of the Mississippi have a much less quantity.

In Idaho there has been found a large low water flow many months after any rain fall. Here the relation to rain fall is absolutely void, the low water flow developing a horse power into the millions, being derived entirely from springs. In Washington he has measured the White river when the high water comes at time of no rainfall, the river being fed by the glaciers in Mount Rainer. The Cedar river near by is nearly the reverse.

The Snoqualime, practically fed by permanent snows in high mountains, shows about 2½ cubic feet per second per square mile at low water, and about 150 cubic feet per second per square mile at high water.

All that the engineer can do as to low water flow is to consider each stream by itself, depending on such physical data of record or memory as he can pick up in each case.

The question of variable head due to varying stages of the river is one that gives much concern in many cases. In the case of the "Economy Light and Power Plant" at Joliet, the writer had to provide for a head varying between 9 feet at extreme high water and a possible head of 14 feet at low water. The wheel setting involved bevel gears, so that six wheels drive a line shaft for the generators. Three of the wheels were speeded to 13 feet head and the other three to 11 feet head. The gear ratios afforded a means to obtain a constant speed of generators.

The speed at which the water wheel governors may be set may vary considerably from what is usually known as the best speed, without any appreciable loss of power or efficiency. When the head varies from 40 to 60 feet, the writer thinks the case might, with a properly arranged hydraulic development, be handled easily on somewhat the same lines as at Joliet. When, however, as has been the case at Oregon City, Oregon, which Mr. Jackson refers to as the Portland, Oregon, plant, the head gets as low as 9 feet at high water and as high as 40 feet at low water, it is more difficult.

As Mr. Jackson says, the low water flow of a stream frequently interferes in an exasperating way with a satisfactory power development. Just to what extent, will depend on what may be the combined cost of a water-driven and steam-driven plant, determined along lines of investigation as to commercial merits which the writer has herein before referred to.

There are some cases existing of long distance electric transmission which are entirely steam-driven; others are entirely water-driven, and many are a combination. The writer has on hand one case at the present time, when the water column horse power at low water is 2000 and high water 200,000 or more. It is close to a good market for power, and he has figured out that a profitable combined development can be made.

Mr. D. W. Mead—In connection with the question of stream flow it may be said that one of the most serious mistakes which can be made in the installation of a hydraulic plant is the overestimate of the quantity of water which may be depended upon at times of minimum flow.

Numerous hydraulic plants have been constructed on small rivers with the expectation that they would develop a considerable constant hydraulic power, and would answer their purpose without supplemental steam plants, and in most cases where supplemental plants have not been provided, such powers have proved unsatisfactory. Only in cases where the waters for power purposes are derived from the Great Lakes, such as the plants at Niagara, Sault Ste. Marie, and Joliet, or where the power developed is only a small percentage of the average power of the stream, should a hydraulic plant be expected to run continuously without some auxiliary power to assist it during the dry weather flow, and during the periods when the flood waters interfere with the power by destroying the head. Such auxiliary plant should always be considered in the inception and design of a hydraulic installation, unless the purpose for which the plant is installed admits of intermittent service.

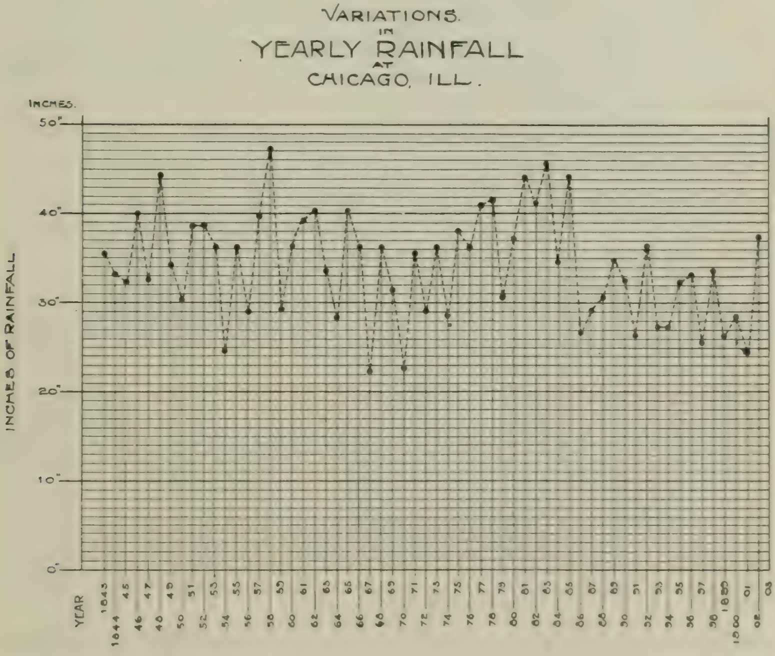
In considering a river for purposes of hydraulic installations, information concerning both head and flow is important.

The question of head will not be here discussed, although its importance is recognized, and it should be carefully investigated both under ordinary conditions and for flood periods. Your attention is here especially called to the question of river flow.

It is impossible, from the nature of the case, to make a close estimate of the average monthly and minimum flows of a river, for such flows partake very largely in their nature of the uncertainties encountered in weather predictions. Stream flows depend, primarily, on rainfall, temperature, atmospheric pressure, and are also influenced largely by the geology and topography of the country, the presence or absence of pervious strata, of swamps and forests, and on the various classes of vegetation, and agricultural improvements on their water shed, and being so largely pre-determined by climatic conditions, will vary from year to year as these conditions likewise vary.

The total annual rainfall at any point varies greatly from year to year, and in many places at the period of minimum rainfall the precipitation is often less than half of the maximum for the same locality (see diagram of annual rainfall at Chicago). Not only does the total yearly rainfall vary upon a watershed in different years, but there is always a considerable variation which will occur in the total precipitation at various points on the shed during the same year, and this variation is almost as great as the yearly variation. It is therefore somewhat difficult to determine the average rainfall on a water shed without an extended series of observations over the whole district considered.

The total annual rainfall, however, has not as great an influence on the dry weather flow of a stream as the distribution of rainfall throughout the year, and it is quite often the case that in years where the rainfall is less than the average, a favorable distribution of the rainfall throughout the year will give a greater dry weather flow and more satisfactory water power than during some years where the total rainfall is greater.



It is true that no exact rule for determining the relation of rainfall and stream flow has been, or, from the nature of the case, ever can be found, for such relations are, of necessity, peculiar to the watershed, and subject to the variation in annual climatic conditions, yet a study of the monthly rainfall records, together with a careful consideration of the physical conditions of the watershed, and such observations of actual flow as may be available, will give a fair basis for estimating flow, if considered in the light of the large amount of stream flow data which is now being yearly recorded.

The water year naturally divides itself into periods beginning, approximately, with December, and ending, approximately, with the following November. The period from December to and including May is usually termed the "storage" period; June, July and

August constitute the "growing" period, and September, October and November the "replenishing" period. These periods vary somewhat each year, and are not, of course, necessarily limited by our artificial division of months. During the first six months the winter snow and the spring rains saturate the ground to a great depth, and a large amount of water is held in storage, both in lakes, swamps, and forests, and in the soils, gravels, etc. That portion of the stored water within the boundaries of the water shed that lie above the level of the bed of the stream is, or may become, available to supply the stream, and is also available for the purpose of evaporation, and for sustaining plant life. Such waters will feed a stream to a certain extent regardless of the amount of rainfall, and will cause a stream flow for several months even without rain, such relation varying more or less with each watershed.

The ground water is called upon to furnish more or less of the stream flow sometimes early in May, and seldom later than the beginning of June, and during June, July and August the rainfall is rarely sufficient to take care of the evaporation and plant growth without something of a draft on the ground water, and the stream flow is usually entirely dependent on the ground water, except during exceptional rain storms. By the end of the growing period the ground water is often so depleted as to be capable of storing five or six inches or more of rainfall.

During the replenishing period the ground again begins to receive its store of water, and with favorable rainfalls, becomes full during the storage period of the winter and spring. Besides the stream flow, the principal source of loss of water falling on a watershed is due, first, to evaporation; second, to the water used by plant life, which is largely absorbed and transpired from the leaves and surface of the plant, so that it may be fairly considered a portion of the actual evaporation of the watershed.

Under some geological conditions there is sometimes a considerable proportion of water which passes through pervious strata far below the bed of the stream, and appears as artesian water at lower elevations and even outside of the boundaries of at least the local stream on which the deposits occur. This last source, however, is usually a minor loss which needs consideration only under special conditions. A careful consideration of all the factors and conditions which have been but briefly and imperfectly outlined above will show a relation between these various factors and stream flow which will afford an approximate method of determining stream flow if sufficient other data is available.

The method of calculation proposed by C. C. Vermeule, C. E., and described in Volume Three of the "Final Report of the Geological Survey of New Jersey," is believed by the writer to be an excellent move in the right direction, and to furnish so good an approximation as to afford an intelligent basis for the consideration of water power problems, if properly applied.

Mr. Vermeule considers the various losses to vary more largely with temperature than any other one feature, and computes the monthly evaporation from the mean annual temperature and the monthly rainfall.

He also establishes a ground flow curve from observations on the given stream, and on this the reliability of the resulting calculations depend, perhaps, more than on any other item.

Ground flow varies largely on different watersheds, and if the variations in this flow are known its effect on the relation between rainfall and stream flow can be calculated with considerable accuracy.

The general relations of the ground water are apparent. If the ground is full, the average monthly flow will be equal to the rainfall less the evaporation.

The observations on which Mr. Vermeule bases his calculations tend to show that if the rainfall is less than sufficient to give a flow equal to about two inches per month, there will be a draft on the ground water causing a depletion which will affect, in turn, the next month's stream flow. The relative depletion and flow are calculated by formulæ, given by Mr. Vermeule, in connection with the ground flow curve.

It will be observed that some considerable data must be obtained before the ground flow curve can be constructed, but that when so obtained, the observed flows and flows calculated by Mr. Vermeule's method agree quite closely. There is absolutely no method of calculating minimum flow on a given watershed without considering the factors mentioned above. The Vermeule method can, of course, be applied to other watersheds where few or no observations of stream flow have been made, by assuming a ground flow curve based on observations of a watershed having similar physical conditions, and from this, calculating the average monthly flow with an approximate degree of accuracy. The degree of accuracy in such cases depends on how closely the physical features of the two watersheds agree. This method so applied cannot lay claim to great accuracy, but it affords at present the best means with which the writer is familiar, of dealing with this problem, and is at least superior to assuming a minimum flow based on the annual rainfall, or on the judgment of the engineer, unsupported by any calculations whatever.

To illustrate the variations in stream flow some data concerning the average monthly flow of various streams of the United States is appended.

The first table shows the average monthly discharge, in cubic feet per second per square mile of drainage area, of various rivers of the United States, arranged in the order of the average monthly flow. From this table it will be observed that the minimum average monthly flow of a stream does not always occur during the same month, and for the consideration of these streams for water power purposes the better arrangement of the recorded flow is not by monthly periods, but in the relative order of the flow.

AVERAGE DISCHARGE IN CUBIC FEET PER SECOND PER SQUARE MILE OF DRAINAGE AREA OF VARIOUS RIVERS OF THE UNITED STATES, FROM 1888 TO 1901.

HUDSON RIVER AT MECHANICSVILLE N.Y.
DRAINAGE AREA 4500 SQ MILES

YEAR	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	AV
JANUARY	4	244	250	164	419	7	150	86	151	89	172	149	130	69	165
FEBRUARY	52	54	74	250	206	102	101	79	104	87	150	117	277	54	154
MARCH	34	164	247	344	241	191	326	93	302	271	449	214	172	180	245
APRIL	423	394	335	445	170	398	247	523	555	424	305	525	502	628	439
MAY	476	147	398	115	437	495	165	152	102	270	246	217	200	260	267
JUNE	128	152	164	71	252	107	55	63	105	243	117	18	91	173	137
JULY	34	128	43	52	206	56	70	57	62	247	57	34	52	79	86
AUGUST	35	95	45	59	122	111	55	87	54	183	114	.31	60	103	83
SEPTEMBER	63	44	137	45	99	133	42	59	64	61	86	46	42	89	78
OCTOBER	162	83	205	33	65	86	81	58	91	56	175	58	47	94	88
NOVEMBER	236	177	203	.91	109	81	142	187	252	222	205	1.42	111	.83	164
DECEMBER	222	293	72	191	93	.60	.97	242	154	320	125	102	113	1.88	169
AVERAGE	177	165	194	162	234	168	137	141	166	208	183	143	150	167	

SHENANDOAH R MILLVILLE W.VA 2995 SQ M.

YEAR	97	'98	99	AV
JANUARY	40	53	166	86
FEBRUARY	337	33	123	164
MARCH	153	51	229	144
APRIL	79	105	110	93
MAY	186	142	85	138
JUNE	46	33	55	45
JULY	42	.28	31	34
AUGUST	30	2.73	.36	113
SEPTEMBER	22	40	34	32
OCTOBER	.23	166	27	72
NOVEMBER	26	85	51	54
DECEMBER	47	138	47	77
AVERAGE	86	.96	83	

POTOMAC R POINT OF ROCK, MD 9654 SQ M.

YEAR	'98	'99	AV
JANUARY	2 46	1.97	2.22
FEBRUARY	.92	3 01	1 97
MARCH	1 65	3.73	2 69
APRIL	1 73	1 25	1 49
MAY	1 96	1 19	1 58
JUNE	.45	57	51
JULY	26	.27	27
AUGUST	2 41	.25	1 33
SEPTEMBER	27	.25	.26
OCTOBER	1 49	18	84
NOVEMBER	.95	.37	65
DECEMBER	1 66	.44	1 05
AVERAGE	1 35	1 12	

DELAWARE R. LAMBERTVILLE, N.J. 6855 SQ M.

YEAR	99
JANUARY	3.13
FEBRUARY	3 67
MARCH	5 78
APRIL	5 08
MAY	1 19
JUNE	57
JULY	99
AUGUST	77
SEPTEMBER	1.35
OCTOBER	93
NOVEMBER	1 50
DECEMBER	1 86
AVERAGE	2 23

GENESEE RIVER N.Y.
[illegible]70 SQ M DRA
RUN OFF IN SEC-FEET PER SQ M

YEAR	93	94	95	96	AV.
JANUARY		140	66	47	.84
FEBRUARY		86	22	91	66
MARCH		331	194	300	2 75
APRIL		339	201	338	2 93
MAY		443	19	17	1 60
JUNE		110	13	39	54
JULY		14	11	24	16
AUGUST		22	12	20	18
SEPTEMBER	33	.93	10	16	38
OCTOBER	38	44	11	174	67
NOVEMBER	54	82	47	82	66
DECEMBER	234	61	132		1 42
AVERAGE		147	62	104	

OSWEGO R N.Y. 5000 SQ MILES

YEAR	97	98	99	00	01	AV.
JANUARY		98	85	61	107	88
FEBRUARY		124	.49	93	37	.76
MARCH		199	97	.99	145	1.35
APRIL	200	151	1.53	280	3.39	2 25
MAY	125	163	135	1.53	2.00	1 55
JUNE	76	166	40	62	163	1 01
JULY	43	36	.15	19	75	38
AUGUST	47	18	12	.13	39	26
SEPTEMBER	25	27	12	.13	37	23
OCTOBER	21	40	11	17	43	26
NOVEMBER	36	88	22	48	58	51
DECEMBER	83	78	.32	180	136	1 02
AVERAGE		99	55	87	115	

BLACK R N.Y. 1889 SQ MILES

YEAR	97	98	99	00	01	AV
JANUARY		118	249	150	1.50	1 67
FEBRUARY	1.14	201	123	3 04	128	1 74
MARCH	334	5.08	267	1.57	318	3.17
APRIL	502	246	735	737	760	5 96
MAY	226	168	297	302	265	2 52
JUNE	144	87	81	86	281	1 36
JULY	47	.60	64	70	.86	.65
AUGUST	121	79	47	.60	113	.84
SEPTEMBER		78	.52	54	163	87
OCTOBER	50	166	54	64	228	1.12
NOVEMBER	220	208	87	265	143	1 85
DECEMBER	250	144	185	224		2 01
AVERAGE	201	172	187	206		

LAKE CHAMPLAIN 7750 SQ M

YEAR	'99	00	'01	AV
JANUARY	137	141	153	1 44
FEBRUARY	125	187	1.28	1 47
MARCH	163	206	133	1 67
APRIL	2.80	286	395	3.20
MAY	317	232	366	3.05
JUNE	179	242	270	2 30
JULY	125	154	132	1 37
AUGUST	.89	120	1.70	1 26
SEPTEMBER	67	92	98	86
OCTOBER	58	85	82	75
NOVEMBER	115	104	78	.99
DECEMBER	147	1.72	1.35	1.51
AVERAGE	1.50	167	178	

MOHAWK R LITTLE FALLS 1308 SQ M

YEAR	98	99	00	01	AV.
JANUARY		211	425	133	2.56
FEBRUARY		115	256	86	1 66
MARCH		288	189	350	2 76
APRIL		620	6.23	5.41	5.95
MAY		2.03	1.58	2.23	1 94
JUNE		78	.61	252	1 30
JULY		.61	.72	86	.73
AUGUST		.17	53	.89	.53
SEPTEMBER	184	23	.48	90	86
OCTOBER	191	39	69	113	1 37
NOVEMBER	221	136	295	1.23	1 94
DECEMBER	1.56	257	248	302	2.41
AVERAGE		170	211	199	

HUDSON R FT EDWARDS 2800 SQ M.

YEAR	99	00	01	AV.
JANUARY	126	115	65	1 02
FEBRUARY	68	255	55	1 26
MARCH	1.79	140	1.23	1 47
APRIL	600	604	755	6 53
MAY	341	227	300	2 89
JUNE	58	101	2.23	1 27
JULY	41	.45	78	55
AUGUST	.26	59	90	.58
SEPTEMBER	48	40	.88	59
OCTOBER	37	.44	96	59
NOVEMBER	182	113	76	1 24
DECEMBER	.84	118	106	1 36
AVERAGE	158	155	171	

KENNEBEC RIVER WATERVILLE ME
4410 SQ MILES

YEAR	93	94	95	96	97	'98	'99	AV.
JANUARY	60	37	46	98	81	73	.53	64
FEBRUARY	53	40	41	64	84	77	54	60
MARCH	93	91	45	298	86	256	73	1 35
APRIL	264	333	543	62	575	676	531	5 06
MAY	694	217	217	387	610	570	481	4 53
JUNE	347	177	146	45	294	226	200	2 16
JULY	131	36	80	121	296	89	114	1 37
AUGUST	5	67	61	71	165	71	73	80
SEPTEMBER	46	67	40	77	04	59	43	[illegible]
OCTOBER	53	85	28	83	60	92	28	61
NOVEMBER	5	85	27	207	129	171	46	1 17
DECEMBER	[illegible]	44	37	62	21	59	51	73
AVERAGE	165	[illegible]	[illegible]	84	217	.97	.46	

ANDROSCOGGIN R RUMFORD FALLS, ME 2220 SQ M.

YEAR	96	'97	'98	99	AV.
JANUARY	149	82	88	98	1.04
FEBRUARY	78	76	77	80	78
MARCH	245	.81	232	80	1 60
APRIL	361	356	419	379	4 29
MAY	339	523	4.21	440	4 31
JUNE	140	315	214	141	2 03
JULY	90	298	84	79	1 38
AUGUST	77	106	.79	64	81
SEPTEMBER	87	72	88	69	80
OCTOBER	93	72	127	70	91
NOVEMBER	138	103	127	.75	1 11
DECEMBER	90	117	98	70	94
AVERAGE	174	183	171	136	

MERRIMAC RIVER LAWRENCE, MASS 4553 SQ. M

YEAR	'90	91	92	93	94	95	96	97	98	99	AV.
JANUARY	153	292	187	65	66	.63	1.44	75	162	1.73	1 38
FEBRUARY	170	296	94	110	94	51	200	101	1.71	1.07	1.40
MARCH	344	5.19	161	236	316	128	462	232	409	2.62	3 07
APRIL	3.79	473	179	342	243	435	400	387	334	5.81	3 75
MAY	314	161	225	4.28	154	1.37	98	222	242	209	2 19
JUNE	173	100	128	97	133	67	.77	279	142	65	1 26
JULY	69	64	105	52	50	57	45	237	58	54	.79
AUGUST	.75	54	106	57	37	48	44	112	83	46	60
SEPTEMBER	184	56	.87	61	40	37	67	61	64	44	72
OCTOBER	270	47	47	79	50	88	114	[illegible]	141	39	85
NOVEMBER	195	54	143	.74	78	2.10	146	128	217	61	1 20
DECEMBER	1.44	90	86	117	67	2.06	96	228	193	61	1 31
AVERAGE	206	1.84	129	1.43	111	127	158	176	1.85	142	1 48

CONNECTICUT R. HOLYOKE, MASS. 8660 SQ M.

YEAR	'96	'97	'98	AV.
JANUARY	126	58	1.19	1.01
FEBRUARY	105	67	1.00	.91
MARCH	314	1.67	409	2 97
APRIL	489	410	3.38	4 12
MAY	112	260	219	1.97
JUNE	62	258	131	1.30
JULY	42	271	45	1.19
AUGUST	34	125	57	72
SEPTEMBER	55	.50	.53	.56
OCTOBER	127	42	140	1 03
NOVEMBER	163	172	182	1 72
DECEMBER	88	251	112	1 50
AVERAGE	1.43	178	160	1 60

In the second table, the writer has re-arranged these records of flow for each year, so that the least flow for any month in the given year is shown on the first line, and the flow of other months is arranged progressively from minimum to maximum. The average for each watershed will, therefore, give a much better criterion of the average hydraulic power to be expected on each watershed during each year than the average monthly flow as shown in the first table.

AVERAGE DISCHARGE IN CUBIC FEET PER SECOND PER SQUARE MILE OF DRAINAGE AREA. MONTHLY DISCHARGE OF EACH RIVER ARRANGED IN ORDER OF MINIMUM FLOW.

	HUDSON RIVER AT MECHANICSVILLE, N. Y. DRAINAGE AREA 4500 SQ MILES															SHENANDOAH R MILLVILLE, W VA 2995 SQ M				POTOMAC R POINT OF ROCK MD 9654 SQ M			DELAWARE R LAMBERTVILLE N J 6855 SQ M
YEAR	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	AV	'97	'98	'99	AV	'98	'99	AV	'99
MINIMUM	34	44	43	33	63	56	42	57	54	56	57	3	42	54	48	22	28	27	26	26	8	22	57
	36	63	45	45	93	71	55	58	62	61	86	46	47	69	61	23	33	31	39	27	25	26	[illegible]
	63	84	72	52	99	81	70	58	64	87	1.14	54	52	79	74	26	33	34	31	.45	25	35	93
	82	95	1.64	59	22	86	81	79	91	89	1.17	58	60	93	90	30	40	.36	35	92	27	60	99
	.02	1.28	1.74	71	1.69	1.02	97	86	1.02	1.83	1.25	58	9	89	1.13	40	51	47	[illegible]	95	34	65	1.19
	1.08	1.52	1.97	91	2.06	1.07	1.07	87	1.64	2.22	1.50	1.02	1.11	94	1.31	42	53	5	49	1.16	44	.80	1.33
	1.4	1.77	2.03	1.23	2.06	1.11	1.42	93	1.05	2.47	1.72	1.17	1.13	1.03	1.47	46	85	55	62	1.49	.57	1.03	1.5
	1.52	1.84	2.05	1.84	2.41	1.53	1.50	1.52	1.51	2.63	1.75	1.42	1.30	1.73	1.75	47	65	85	79	1.65	1.19	1.42	1.86
	2.22	1.97	2.41	1.91	2.80	1.60	1.58	1.54	1.54	2.70	2.05	1.49	1.72	1.90	1.96	79	1.38	1.10	1.09	1.73	1.25	1.49	3.13
	2.36	2.44	2.50	2.59	4.19	1.97	1.68	1.87	2.52	2.71	2.46	2.14	2.00	1.88	2.38	53	1.42	1.23	1.39	1.96	1.97	1.97	3.67
	4.73	2.93	3.35	3.94	4.37	3.98	2.47	2.42	3.02	3.20	3.05	2.17	2.77	2.60	3.2	86	.66	1.66	1.73	2.41	3.01	2.71	5.08
MAXIMUM	4.76	3.04	3.98	4.45	4.79	4.95	3.28	5.29	5.55	4.24	4.49	5.25	5.02	6.26	4.67	3.37	2.73	2.29	2.80	2.46	3.75	3.20	5.78

	GENESEE RIVER, NY 1070 SQ. M. DR. A					OSWEGO R AT OSWEGO, N.Y. 5000 SQ. MILES						BLACK R N.Y. 1889 SQ. MILES						LAKE CHAMPLAIN 7750 SQ M				MOHAWK R N Y LITTLE FALLS 1308 SQ M					HUDSON R FT EDWARDS 2800 SQ M			
YEAR	'94	'95	'96	'97	AV	'98	'99	'00	'01	'02	AV	'97	'98	'99	'00	'01	AV	'99	'00	'01	AV	'99	'00	'01	'02	AV	'99	'00	'01	AV
MINIMUM	14	10	.16		13	18	11	13	37		20		60	47	54	86	62	58	85	78	74	[illegible]	48	86		50	26	40	55	.40
	22	17	17		19	27	12	.13	37		22		.78	52	60	1.13	76	67	92	82	80	23	53	86		54	37	44	65	49
	44	11	20		25	36	12	17	39		26		79	54	64	1.28	81	89	1.04	98	97	39	61	.89		63	41	45	76	54
	61	12	24		32	40	15	19	43		29		87	64	70	1.45	91	1.15	1.20	1.28	1.21	61	69	90		73	48	59	78	62
	82	13	39		45	78	22	48	58		52		1.18	81	.86	1.50	1.09	1.25	1.41	1.32	1.33	78	72	1.15		88	58	[illegible]	88	.82
	86	19	.47		51	89	32	61	75		64		1.44	87	1.50	1.63	1.41	1.25	1.54	1.35	1.37	.5	1.58	1.23		1.32	68	[illegible]	.90	90
	93	22	82		66	98	40	62	1.07		77		1.06	1.23	1.57	2.28	1.69	1.37	1.72	1.35	1.48	1.30	89	1.33		51	[illegible]	5	96	[illegible]
	1.10	47	91		.83	1.24	.49	93	1.36		1.01		1.68	1.85	2.24	2.65	2.11	1.47	1.87	1.53	1.62	2.03	2.48	2.20		2.24	79	1.8	1.06	.34
	1.40	66			1.03	1.51	.85	.95	1.45		1.20		20	2.49	2.65		2.38	1.65	2.06	1.70	1.80	2.11	2.95	2.52		2.53	82	1.40	23	48
	3.31	1.32	1.74		2.12	1.63	.97	1.53	1.63		1.92		2.08	2.67	3.02	2.81	2.65	79	2.32	2.70	2.27	2.57	2.96	3.02		2.85	1.84	2.27	2.23	2.11
	3.39	1.94	3.00		2.78	1.66	1.35	1.80	2.00		1.70		2.46	2.97	3.04	3.8	2.91	2.80	2.42	3.66	2.96	2.88	4.23	3.50		3.54	3.41	2.55	3.00	2.99
MAXIMUM	4.43	2.01	3.38		3.27	1.99	1.53	2.80	3.39		2.49		5.08	7.35	7.37	7.60	6.85	3.17	2.86	3.95	3.33	6.20	6.23	5.41		5.95	6.00	6.04	7.55	6.53

	KENNEBEC RIVER, WATERVILLE, ME 4410 SQ. MILES.								ANDROSCOGGIN R RUMFORD FALLS, 2220 SQ.M.					MERRIMAC RIVER LAWRENCE MASS 4553 SQ M.											CONNECTICUT R HOLYOKE MASS 8660 SQ M			
YEAR	'93	'94	'95	'96	'97	'98	'99	AV	'96	'97	'98	'99	AV	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	AV	'96	'97	'98	AV
MINIMUM	36	37	.28	.62	.60	28	.59	44	77	72	77		75	39	47	47	52	.37	37	44	48	.58	.39	48	34	42	45	40
	46	40	40	.64	81	43	59	53	78	72	79		.76	.75	54	86	.57	.40	.48	45	.61	64	44	57	42	56	57	50
	.51	.42	.41	.71	84	46	71	.58	87	.76	84		.82	.44	54	87	61	.44	57	.67	.75	.83	44	71	55	58	63	59
	51	.62	.45	.77	86	.51	73	.64	90	81	88		.86	1.53	54	94	65	.50	.57	.77	.91	1.41	54	85	62	67	1.00	76
	.53	.67	46	.85	1.04	55	77	69	90	82	88		.87	1.70	64	1.05	74	50	63	.96	1.12	1.42	[illegible]	94	.86	1.25	1.12	1.08
	.33	.85	61	.98	1.21	54	.89	80	.95	1.03	.98		.98	1.73	90	1.04	79	66	67	.98	1.28	1.62	61	1.13	1.05	1.47	1.19	1.30
	.60	85	.80	1.21	1.29	73	.92	.91	1.38	1.06	27		1.24	84	1.00	1.26	97	67	88	1.14	2.22	1.71	65	1.24	1.12	1.74	1.31	[illegible]
	.95	.91	1.27	1.25	1.65	79	1.17	1.13	1.40	1.17	[illegible]		1.28	1.95	1.61	49	1.10	78	1.28	1.44	2.28	1.93	1.07	1.39	[illegible]	[illegible]	1.40	[illegible]
	1.31	1.30	1.37	2.07	2.94	1.14	2.26	1.77	1.49	2.98	2.14		2.20	2.70	2.92	1.61	1.17	.94	37	[illegible]	[illegible]	[illegible]	[illegible]	1.84	[illegible]	[illegible]	1.82	1.89
	1.64	1.77	1.46	2.98	2.96	2.00	2.36	2.20	2.49	3.15	2.32		2.64	[illegible]	2.96	79	2.36	1.33	2.06	2.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	3.47	2.17	2.17	3.87	5.75	3.81	5.70	3.99	3.39	3.56	4.19		3.71	3.44	4.73	1.87	3.42	[illegible]	[illegible]	4.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.58	3.08
MAXIMUM	6.92	3.33	5.43	6.21	6.10	5.31	6.76	5.72	5.61	5.23	4.21		5.02	3.79	5.19	2.25	4.28	[illegible]	4.35	4.62	3.87	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.09	[illegible]

From this second table it will be seen that the average minimum monthly flow of the Hudson river at Mechanicsville, N. Y., is 0.48

cubic feet per second per square mile, the minimum for any year during the period of the observations being 0.31, and the maximum 0.63.

On the Oswego river in the same state, with no very great difference in total annual rainfall, the average minimum monthly flow is 0.20, the minimum for any year being 0.11, and the maximum 0.37. These figures, it must be remembered, are averages for each month, and the actual minimum flow for the period is often a much less quantity.

From these records it will be seen that minimum flow cannot be based on the mean annual rainfall. This is furthermore more fully demonstrated by the following table, taken from the report of E. Kuichling, on the Water Supply for the New York Barge Canal, showing the drainage area, mean annual rainfall, and maximum and minimum discharge in cubic feet per second per square mile of various streams in the United States and foreign countries.

From this table it will be noted that the recorded minimum of some of the southern streams seems to be between 0.5 and 0.6 cubic feet per second per square mile. While numerous other streams will vary from 0.20 to 0.40, nevertheless a large proportion of the streams mentioned have minimum flows of 0.10 and less.

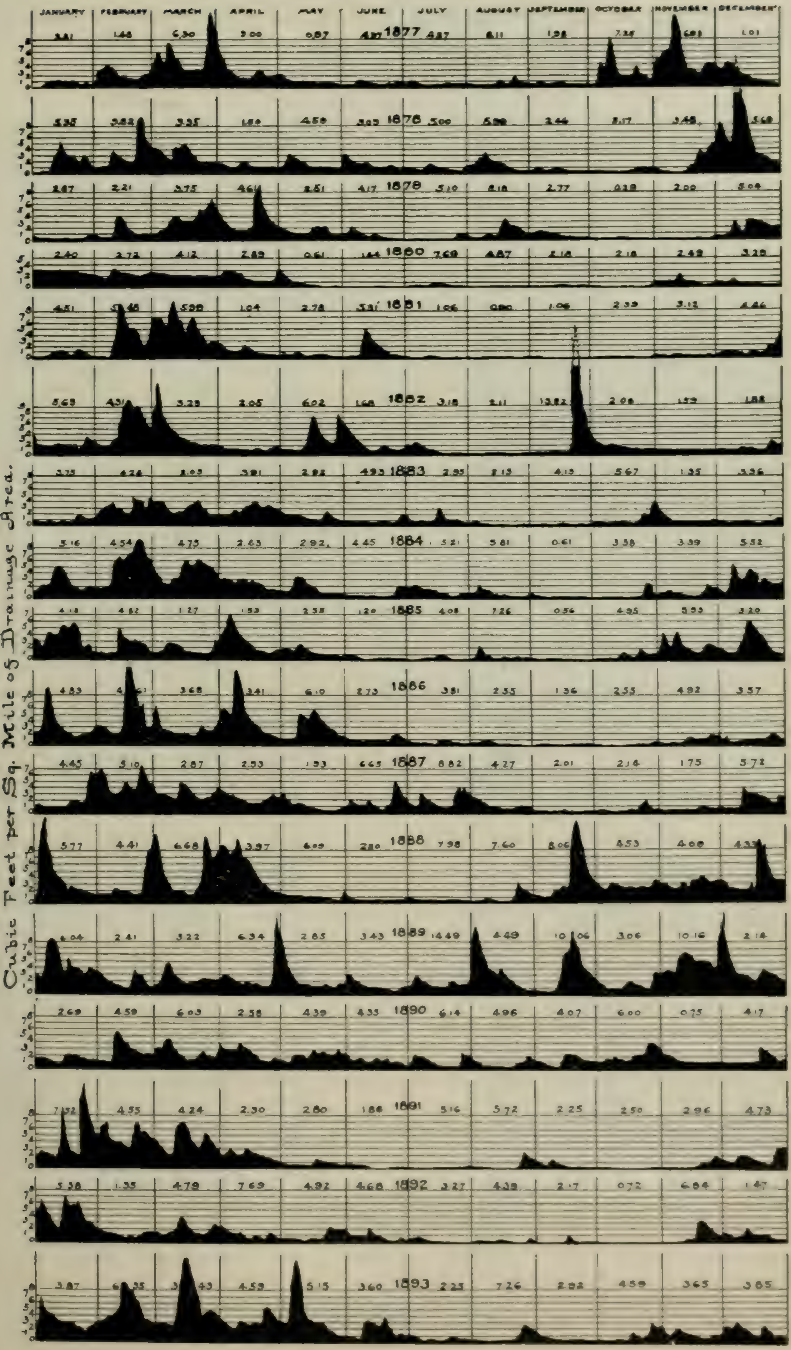
From these very great variations it is apparent that the greatest care is necessary in the calculations precedent to the establishment of a hydraulic plant, and that even where an auxiliary steam plant is established, a careful consideration of the minimum hydraulic flow is essential, in order to determine the necessary size of the same, unless the auxiliary plant is built of sufficient size to furnish the maximum power required at any time when the conditions make it desirable so to do.

These calculations are also important for determining the value of storage, and the necessary extent of the same when it is found desirable to attempt to control the flow of the stream; also for determining the financial value of a power, and the necessary charges for power, in order to make the investment financially successful when the plant is to be operated a portion of the year by steam.

I wish also to call to your attention the diagrams illustrating the daily flow of the Passaic river in cubic feet per second per square mile, which I have had constructed from diagrams of the flow of this stream published in the Third Volume of the Final Report of the State Geologist of New Jersey. These diagrams illustrate the great variation in stream flow from year to year, and also the fact that the average monthly flow of stream may be made up of considerable variation in daily flow. These diagrams afford an interesting illustration of the relation of monthly rainfall and stream flow.

In conclusion, it may be said that while the loss of head due to

DAILY FLOW OF PASSAIC RIVER LITTLE FALLS, N.J.



NOTE
HORIZONTAL DIVISIONS DENOTE CUBIC FEET PER SECOND PER SQUARE MILE OF DRAINAGE AREA

high water is important, the effect of high water is for a brief period only, as these diagrams will show, while the dry weather flow is usually of some months duration.

DRAINAGE AREA, 500 TO 1000 SQUARE MILES.

STREAM AND LOCALITY.	Drainage Area Sq. Miles	Mean Annual Rainfall Inches	Discharge Cu. Ft. Per Sec. Per Sq. Mile	
			MAX.	MIN.
I. AMERICAN STREAMS.				
Broad river at Carlton, Ga	762	47.73	22.21	.394
Coosawattee river at Carters, Ga	532	52.73	15.17	.588
Des Plaines river at Riverside, Ill	630	29.75	14.23	.000
Etowah river at Canton, Ga	604	52.73	31.50	.405
Flint river at Molina, Ga	892	52.73	7.37	.062
French Broad river at Asheville, N. C	987		7.88	.660
Greenbriar river, mouth Howard's cr., W. Va.	810	40.70		.120
Housatonic river, Massachusetts	790			.165
Little Tennessee river at Judson, N. C	675		56.40	.408
Mahoning river at Warren, O	596			.017
Mahoning river	967			.026
Monocacy river at Frederick, Md	665	38.77	16.98	.116
North river at Port Republic, Va	804	38.77	29.78	.220
North river at Glasgow, Va	831	38.77	44.80	.180
Olentangy river at Columbus, O	523			.014
Passaic river at Paterson, N. J	791	45.00		.190
Potomac river, no. branch at Cumberland, Md.	891	38.77	22.82	.045
Potomac river at Cumberland, Md	920	38.77	19.46	.022
Raritan river at Bound Brook, N. J	879	45.94	59.30	.140
Schoharie creek at Fort Hunter, N. Y	948	39.25	44.00	
Shenandoah river at Port Republic, Va	770	38.77		.167
Tuckasagee river at Bryson, N. C	662		45.30	.603
II. FRENCH STREAMS.				
Armancon river at Aisy	575		49.20	.011
Armancon river at Tonnerre	853			.034
Marne river at St. Dizier	915	30.70	7.73	.101
Meuse river at Pagny-la-Blanchecote	573			.039
Meuse river at Chalaines	607	31.51		.041
Meuse river at Pagny-sur-Meuse	734			.056
Meuse river at Vignot	817			.085
Meuse river at Mt. Mihiel	914			.078
III. GERMAN STREAMS.				
Ihna river at Stargard	672	26.60	15.50	.137
Jagst river at its mouth	708	29.50		.200
Kocher river at its mouth	768	29.50		.221
Lippe river at Hamm	965		9.75	.235
Malapane river at Czarnowanz	773	25.04	14.35	.274
Oppa river at Strebowitz	805	24.40	21.95	.256
Stober river at its mouth	620	22.70	3.65	

DRAINAGE AREA, 1,000 TO 2,500 SQUARE MILES.

STREAM AND LOCALITY.	Drainage Area, Sq. Miles.	Mean Annual Rainfall, Inches.	Discharge Cu. Ft. Per Sec. Per Sq. Mile.	
			MAX.	MIN.
I. AMERICAN STREAMS.				
Androscoggin river at Rumford Falls, Me	2,220	40.39	25.00	.475
Broad river at Gaffney, S. C	1,435	47.73	13.05	.550
Catawba river at Catawba, N. C	1,535		34.30	.553
Chattahoochee river at Oakdale, Ga	1,560	48.91	21.75	.432
Genesee river at Mt. Morris, N. Y	1,070	38.09	39.20	.094
Greenbriar river at Aederson, W. Va	1,344	44.86	41.55	.041
James river at Buchanan, Va	2,058	40.83	15.56	.146
Neuse river at Raleigh, N. C	1,000			.193
Neuse river at Selma, N. C	1,175		6.70	.064
Ocmulgee river at Macon, Ga	2,425	49.23	14.92	.157
Oconee river at Carey, Ga	1,346	49.31	7.44	.283
Oostannala river at Resaca, Ga	1,527	52.47	14.50	.389
Potomac river at Cumberland, Md	1,364	35.28		.018
Saluda river at Waterloo, S. C	1,056		12.08	.275
Schuylkill river at Philadelphia, Pa	1,800			.170
Schuylkill river at Fairmount, Pa	1,915		12.17	.013
Scioto river at Columbus, O	1,070			.004
Scioto river at Shadeville, O.	1,670			.015
Tar river at Tarboro, N. C	2,290		6.38	.074
Youghiogheny river at Ohio Pyle, Pa	1,775			.060
II. FRENCH STREAMS.				
Aisne river at Biermes	1,341			.085
Aisne river at Berry-au-Bac	2,120			.092
Ainse river at Berry-au-Bac	2,120		7.58	
Loing river at its junction with the Seine	1,785	28.40		.046
Lys river	1,420		1.74	.099
Marne river at La Chaussee.	2,297			.010
Marne river at Chalons.	2,497			.010
Meuse river at Verdun	1,219	28.33		.110
Oise river at Chauny	1,575			.104
Seine river at Troyes	1,314			.051
III. GERMAN STREAMS.				
Bober river at Sagan	1,638	39.20	17.40	.389
Drage river at its mouth	1,234		2.11	.356
Ill river at Strasburg	1,294		9.15	.327
Kuddow river at Usch	1,830	18.90	19.30	.405
Lahn river at Diez	2,008	25.60	12.80	.123
Lippe river at Wesel	1,890		11.62	.198
Main river above mouth of the Regnitz river	1,725	27.44		.224
Netze river at Antonsdorf.	1,086			.063
Netze river above Eichhorst	1,130			.046
Oder river at Hoschialkowitz	1,440	21.60		.155
Oder river at Annaberg	1,800	24.60	27.00	219
Oder river at Olsau	2,250	24.60	43.90	274
Obra river at Moschin	1,325			.101
Ruhu river at Mulheim	1,728		33.80	.176
Saale river at its junction with the Main	1,070	27.76		.081
Welna river at Kowanowko, near mouth	1,013		3.14	.077

DRAINAGE AREA, 2,500 TO 5,000 SQUARE MILES.

STREAM AND LOCALITY.	Drainage Area Sq. Miles.	Mean Annual Rainfall Inches.	Discharge Cu. Ft. Per Sec, Per Sq. Mile.	
			MAX.	MIN.
I. AMERICAN STREAMS.				
Black Warrior river at Tuscaloosa, Ala.....	4,900		38.80	.018
Broad river at Alston, S. C................	4,609		10.26	.394
Cape Fear river at Fayetteville, W. Va.....	4,493		1.17	.076
Catawba river at Rock Hill, S. C..........	2,987		21.96	.445
Chattahoochee river at West Point, Ga.....	3,300	52.92	17.37	.252
Connecticut river at Dartmouth, N. H.....	3,287			.306
Coosa river at Rome, Ga..................	4,001	52.73	11.42	.225
Crow Wing river, Minnesota..............	3,576	30.84	2.84	.250
Dan river at Clarksville, Va...............	3,749	38.28	8.80	.107
Hudson river at Mechanicsville, N. Y......	4,500	41.61	15.50	.189
Kennebec river at Waterville, Me..........	4,410		25.20	.006
Merrimac river at Lowell, Mass...........	4,085		19.83	.310
Merrimac river at Lawrence, Mass.........	4,553		23.40	.016
Mohawk river at Rexford Flats, N. Y	3,384		23.10	
Mohawk river at Cohoes, N. Y	3,444	38.65		.232
Ocanee river at Dublin, Ga................	4,182	49.31	6.69	.021
Potomac river at Dam No. 5, Md..........	4,640	38.77	22.15	.078
Savannah river at Calhoun Falls, Ga	2,712	47.73	.96	.518
Shenandoah river at Millville, W. Va......	2,995	39.56	11.44	.203
Staunton river at Clarksville, Va...........	3,546	38.28	10.30	.157
Susquehanna river, w. br., Williamsport, Pa.	4,500		11.60	.178
Tallapoosa river at Milstead, Ala.........	3,840		9.50	.091
Yadkin river at Salisbury, N. C............	3,399		23.55	.225
Yadkin river at Norwood, N. C........ ...	4,614		13.70	.284
II. FRENCH STREAMS.				
Aisne river at Soissons....................	3,040		6.43	.081
Aisne river, above junction with the Oise river	3,285	23.50	5.95	.096
Eure river at its mouth	2,980	22.30	2.72	.076
Isere river at its mouth	4,360		21.00	.780
Marne river at Chateau Thierry	3,332			.127
Meuse river at Sedan.....................	2,560	28.33	8.05	.194
Meuse river at Fumay....................	3,700	28.33	4.04	.191
Seine river at Bray	3,750		4.05	.003
Seine river at Nogent-sur-Seine.......	3,594			.103
Yonne river at Sens......................	4,270		9.09	.106
Yonne river at Nogent-sur-Seine....	4,300	30.80	6.37	.140
III GERMAN STREAMS.				
Main river, below mouth of the Regnitz river	4,650	27.44		.186
Moselle river at Metz.....................	3,550	29.48	14.92	.199
Mur river at Graz...........	2,959		12.98	.243
Neckar river at Heilbronn	3,155			.146
Neckar river at Offenau..................	4,770		33.35	.167
Oder river at Ratibor.....................	2,580	24.60	21.20	.306
Oder river at Kosel......................	3,520	24.60	14.10	.128
Oder river at Krappitz....................	4,150	24.60	3.86	.187
Regnitz river at its junc. with the Main river	2,920	25.60		.164

DRAINAGE AREA, 5,000 AND OVER SQUARE MILES.

STREAM AND LOCALITY.	Drainage Area, Sq. Miles.	Mean Annual Rainfall, Inches.	Discharge Cu. Ft. Per Sec. Per Sq. Mile. MAX.	MIN.
I. AMERICAN STREAMS.				
Connecticut river at Holyoke, Mass.	8,660		13.26	.029
Connecticut river at Hartford, Conn.	10,234	44.53		.310
Connecticut river at Hartford, Conn.	10,234	44.53	20.27	.510
Coosa river at Riverside, Ala.	6,850	48.08	10.53	.197
Delaware river, New Jersey	6,750		50.00	.300
Delaware river at Stockton, N. J.	6,790	45.29	37.50	.170
Delaware river at Lambertsville, N. J.	6,855	45.29	9.71	.364
James river at Richmond, Va.	6,800	40.83		.191
Kanawha river at Charleston, W. Va.	8,900	40.70	13.49	.123
Mississippi river	7,283	32.64	1.49	.261
Mississippi river above St. Paul	36,085	25.75	19.73	.045
Mississippi river	164,534			.190
Mississippi river	526,500			.050
Mississippi river	1,214,000			.210
Missouri river	17,615	15.70		.100
New river at Fayette, W. Va.	6,200	40.70	13.49	.189
Ohio river at Pittsburg, Pa.	19,990			.114
Ohio river	200,000	41.50		.270
Oswego river at Oswego, N. Y.	5,013	37.69		.230
Potomac river at Point of Rocks, Md.	9,654	39.35	19.40	.083
Potomac river	11,043	38.77	42.60	.170
Potomac river at Georgetown, D. C.	11,124	38.77	15.70	
Potomac river at Great Falls, Md.	11,427	45.36	41.15	.215
Potomac river at Great Falls, Md.	11,476	45.36	15.25	.093
Potomac river at Chain Bridge, D. C.	11,545	38.77	17.16	.165
Red river, Arkansas	97,000	39.00	2.32	
Roanoke river at Neal, N. C.	8,717	38.21	7.38	.229
St. Croix river, Minnesota	5,950	32.58	6.00	.424
Savannah river at Augusta, Ga.	7,294	47.73	42.50	.272
Susquehanna, W. branch, at Northumberland	6,800		17.53	.074
Susquehanna river at Harrisburg, Pa.	24,030		18.88	.092
Tennessee river at Chattanooga, Tenn.	21,418		20.78	.199
II. FRENCH STREAMS.				
Loire river at Nevers	6,560		23.10	.070
Loire river, between Maine and Vienne rivers	9,950			.255
Marne river at Charenton	5,057			.016
Marne river at its junction with the Seine	5,295	30.70	4.67	.080
Meuse river at Maestricht	8,240	42.50	5.51	.146
Meuse river at Maeseyck	8,480	42.50	7.36	.244
Meuse river above Ruremond	8,750		3.01	.317
Oise river at Creil	5,622		3.14	.194
Rhone river at Lyons	18,000	36.32	11.83	.333
Seine river at Port a l'Anglais	17,624			.046
Seine river at Paris	20,000	21.27	5.80	.085
Seine river at Mantes.	25,135		3.09	.091
Seine river at mouth of the Eure river	28,583		3.09	
III. GERMAN STREAMS.				
Elbe river at Torgau	22,000	27.09	2.89	.144
Main river above mouth of Saale river	5,820			.182
Main river below mouth of Saale river	6,900			.166
Main river above mouth of Tauber river	7,290			.167
Main river below mouth of Tauber river	8,000			.167
Main river at Frankfort	9,610		12.50	.121
Memel river at Tilsit	38,600		4.02	.813
Moselle river at Kochem	10,253		8.52	.174
Moselle river at Coblenz	10,840	24.76	13.04	.166

DRAINAGE AREA, 5,000 AND OVER SQUARE MILES.

STREAM AND LOCALITY	Drainage Area Sq. Miles.	Mean Annual Rainfall Inches.	Discharge Cu. Ft. Per Sec. Per Sq. Mile, MAX.	MIN.
III. GERMAN STREAMS.				
Neckar river at Heidelberg	5,321		32.17	.215
Neckar river at Mannheim	5,395		31.02	
Oder river at Ohlau	7,750	24.60	4.17	.215
Oder river at Breslau, below the Ohle river.	8,330	24.60	10.40	.209
Oder river at Steinau	11,412	24.02	.95	.229
Oder river below mouth of the Warthe river	28,319	23.62	.61	.212
Saale river at Rothenburg	7,282	27.76	5.41	.120
Warthe river at Pogorzelice.	7,900			.164
Warthe river at Posen	9,620		6.37	.100
Warthe river at Landsberg	20,020	21.65	2.56	.192

Mr. E. Gonzenbach—I would like to ask Mr. Mead if, in computing his factor of minimum flow for certain drainage areas, he means to apply the one factor for all work, or work out a certain factor for one particular stream and vary that according to local conditions from month to month?

Mr. D. W. Mead—There is no question whatever but that all local conditions must be taken into consideration, and all formulae for determining stream flow must be varied in accordance with these conditions. The various weather conditions, including barometric pressure, precipitation and temperature, must be considered. Precipitation must be considered more in relation to the monthly distribution than the total annual rainfall. There is a very remote relation between the annual rainfall and minimum stream flow, and a much closer relation between the monthly rainfall and monthly stream flow. The monthly rainfall will give a very fair basis for calculation of monthly stream flow if the various other factors mentioned are known and are taken into account.

Mr. Gonzenbach.—From that I understand that you wish to take the minimum months of the year, which means the minimum precipitation, and from that as a basis work out the minimum flow and call this the average minimum flow of the stream.

Mr. Mead.—No; stream flow is not dependent on the rainfall of any one month, but more on the distribution of the rainfall through the year. It is a question of both flow and rainfall. The subject is a very broad one and it is impossible to go into it in full detail at this time, but the general points are these: Through the winter and early spring the soil is saturated and heavy rainfalls at such periods will develop floods on the watershed, while in summer time a rainfall which may sometimes amount to two or three inches on a water shed will have very little influence on the immediate flow. These show that often in summer there is a depletion of the ground water, and that the ground water, during long dry spells, supplies the stream flow. In order to calculate the flow of a stream the relation between the ground water and the stream flow must be determined, to an extent at least, or must be judged from those relations that have been determined on similar water sheds. From the known rainfall, the known evaporation, and the known relation between the stream flow and ground water, can be determined quite closely the flow which will take place during each month of the year when the distribution of the monthly rainfall has been carefully recorded.

Mr. L. K. Sherman—I want to say a good word for the work of the United States Geological Survey on their stream measurements. I had occasion to report on the water power of a stream recently. Their reports proved of great value. It is far better to have the Government do this work of recording stream measurements than to use any catchment formula or to depend on statements of the neighboring oracles regarding the maximum and minimum stages of the stream. I have little use for any catchment formula. The work of the United States Geological Survey is certainly of great value in propositions for the development of water power.

CLOSURE.

Dugald C. Jackson—On account of my brother's absence in California, I have the privilege of representing him as the writer of the paper this evening, and will undertake the closure of the discussion.

Mr. Johnston raises the following proposition early in his discussion: that the economics of construction is not a question of engineering; but he has proved quite clearly that he considers this question of extreme moment in his own practice, and if he should neglect the question in any of his structures he might reasonably expect to fail in his duty as an engineer. It should be understood that economics of design and construction is not synonymous with a duty which is not usually within the province of the engineer, namely, "financing," though the engineer may be wisely conversant with the requirements thereof.

I think also that admirable proof exists in his work relating to certain dam structures, to support the statement made in the paper to the effect that poor workmanship is more to be feared, when proper design is reasonably looked after, than lack of theory. Mr. Johnston's dams have stood, as far as I have learned, and he has doubtless supervised their construction very carefully. He has designed them properly to begin with, and I think they have stood because, first, they were designed properly, and second, they were properly built; while if poor workmanship had gone into them they would have been in imminent danger of destruction at the first flood even if the design had been perfect.

The question of minimum flow per square mile was dealt with by Mr. Johnston and also by Mr. Mead. The paper of the evening contains the statement that a rule for determining the inter-relation between the minimum flow of a river and the miles of drainage area "is yet to be found." When reading this a few minutes ago I remarked that perhaps we would never be able to find a fixed inter-relation and I am quite inclined to agree with Mr. Johnston that it is indeterminate when considered at large. On the other hand I am equally inclined to agree with Mr. Mead that in *many situations* there may be certain factors applied which will show the approximate relations (for the particular locations) which exist between minimum flow and square mile of drainage area, but the factors referred to must be applied with great care. Not only are the conditions named by Mr. Vermeule likely to control the factors under consideration, but if one goes farther west he is likely to be met by the question of elevation, which affects the proportional run-off as compared with the annual rainfall and its distribution during the months. However, if all conditions are considered, there does appear to be a relation between the minimum flow of a stream and the rainfall distribution, and I cannot agree with Mr. Johnston in his generalized proposal that no relation at all exists between the annual rainfall and minimum flow in a stream. Such a relation can usually be shown to exist for any stream, but its exact value is dependent upon a wide range of conditions which are not always known.

It might be added in connection with Mr. Sherman's remarks that a large number of western streams that now figure in projected electric power transmission installations are located in regions not yet covered by the governmental surveys and stream gaugings. Other means of arriving at an estimate of minimum stream flow must evidently be relied upon in such situations, as is related in the paper.

REPORT OF TESTS OF THREE NEW PUMPS FOR CHICAGO WATER WORKS, MADE IN 1902.

The following report of the tests of three 20,000,000-gallon Worthington pumps of the Chicago Water Works is published in the JOURNAL as a matter of record and of interest to our readers. The thanks of the Publication Committee are hereby returned to Mr. John Ericson, city engineer, for permission to use, and to Messrs. R. W. Hunt & Co., for supplying the data, tables, etc., of this report.

Chicago, October 16, 1902.

F. W. Blocki, Esq., Commissioner of Public Works,
City Hall, Chicago.

DEAR SIR.—The contract between the city of Chicago and Henry R. Worthington for the 20,000,000-gallon pumping engines at the Central Park Avenue and the Springfield Avenue pumping stations having been practically completed, steps were taken about two months ago to organize the board of experts to conduct the duty tests, as provided in your contract. The city of Chicago chose Robert W. Hunt & Company as their representative, and Henry R. Worthington chose Mr. F. J. Oakes. These two members settled upon Mr. T. T. Johnston as the third member of the board.

This board made the tests on the three engines at the Central Park Avenue pumping station, and attached hereto you will please find the requirements as set forth in the contract, Henry R. Worthington's acceptance of the limit on the duty of 150,000,000-foot pounds when the super-heaters were installed, together with description of engines, logs and results, the full report being signed by the board of experts.

The undersigned beg to submit the following final report of the duty and capacity trial of three (3) twenty million (20,000,000) gallon pumping engines installed at the Central Park Avenue pumping station, in the city of Chicago, by the Henry R. Worthington Company, of Brooklyn, New York.

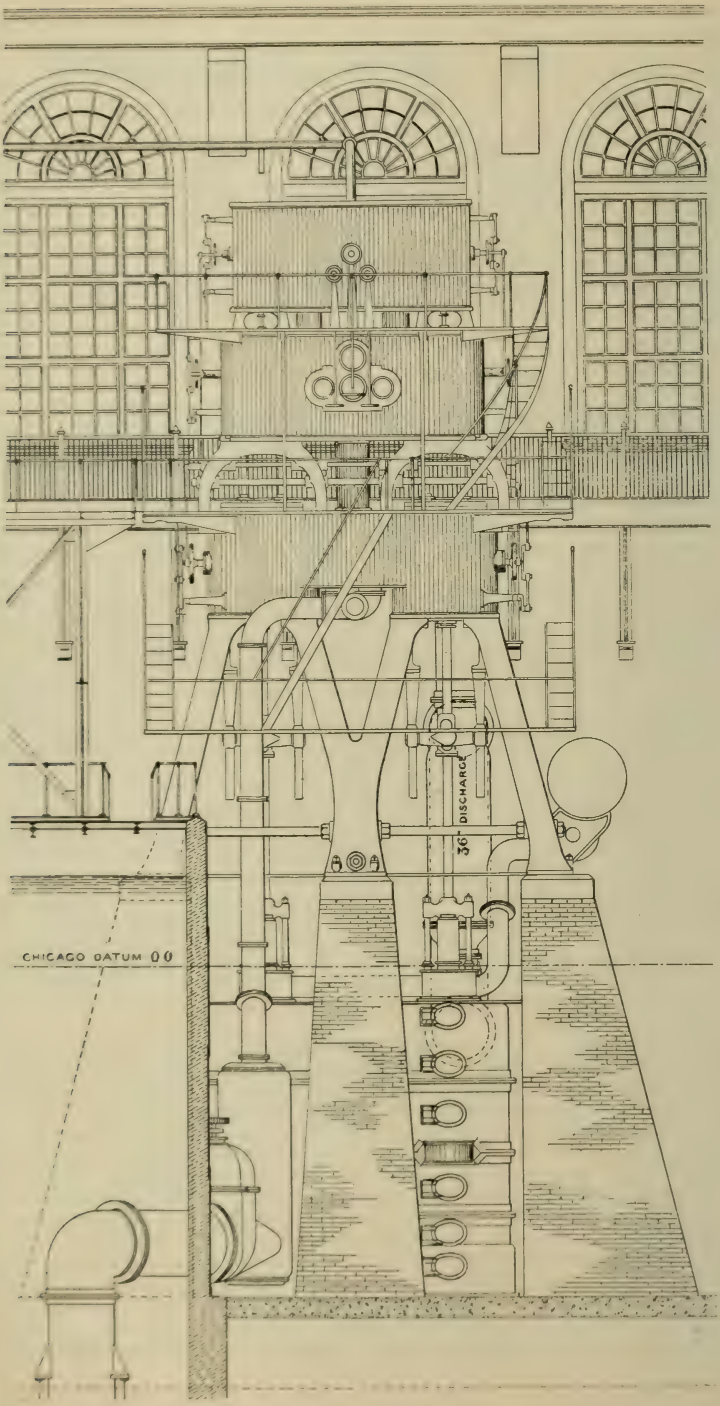
The object of the trial was to determine the capacity and duty of the engines, and to determine whether or not the engines met the conditions of the contract as set forth in the specifications, which provide that:—

"Said experts shall have full power to make examinations of all parts of the machinery, at such times as they may deem necessary, to determine beyond a doubt the character, capacity and duty of the engines, boilers and other parts.

REPORT OF EXPERTS. The experts shall make a full report to the Commissioner of Public Works, in writing, on the tests for duty and capacity herein prescribed, and shall certify therein the duty and capacity of each engine and whether or not each and all of the engines have fully complied with the requirements of these specifications.

The duty required to be developed by each engine shall not be less than 135 million pounds of water raised one foot high for each 1000 pounds of commercially dry steam, and shall have ample power and capacity to raise from the pump well, directly into the supply pipe system not less than 20 million gallons of water per 24 hours under a head equivalent to 150 feet above the surface of the water in said well with the steam pressure at the throttle not to exceed 140 pounds per square inch.

In case any of the engines exceed the duty above prescribed, then the city of Chicago agrees to pay to the contractors, as a reward for the superior efficiency of the engine, the sum of $1,000 for each million foot pounds excess, or pro rata for any fraction thereof, for each engine. In case either engine fails to perform a duty of 135 million foot pounds per 1000 pounds of commercially dry steam during the test, the contractors shall pay to the city of Chicago, as an agreed measure of damages for lack of efficiency of the engine, in the ratio of $2,000 for each one million foot pounds which the duty falls below 135 million. A failure in capacity or duty exceeding three per cent of the requirements of the contract and specifications, will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subject the machinery to rejection by the Commissioner of Public Works, or to such forfeiture as said commissioner, in his discretion, may determine.

In case of the rejection of the machinery, the contractor agrees to repay to the city of Chicago all moneys paid on account, and waives all right to contract and furnish machinery to take the place of the rejected machinery, and besides agrees to leave the city of Chicago in possession and use of rejected machinery for two years after date of rejection, in order to give the city of Chicago opportunity to purchase and erect new machinery."

These specifications were further modified by an agreement between the city of Chicago and the Henry R. Worthington Company, as shown by certain correspondence (copies of which are on file in the city hall), allowing the use of superheaters and limiting the bonus on each engine to an amount represented by a duty of 150,000,000-foot pounds per 1000 pounds of commercially dry steam. The agreement between the city of Chicago and the Henry R. Worthington Company in reference to the boilers, states, "that ten pounds of water will be evaporated at a temperature of 212 degrees in the boilers per pound of combustible. The coal to be used shall be of the best quality of bituminous, as stated in the specifications."

DESCRIPTION OF ENGINES.

The engines are of the duplex vertical type with high duty attachment, double acting outside packed plungers, and triple expansion steam cylinders. The high intermediate and low pressure pistons on each side are double acting and connected by one high pressure, two intermediate and one low pressure piston rod, with two plunger rods connected to the crosshead. The low pressure cylinders are supported on "A" frames directly over the pumps, the intermediate and high pressure cylinders being supported over the low pressure cylinders by distance pieces.

The pumps have four suction openings leading from a main suction pipe from the well, in which the condenser is placed. The four discharge openings converge together and lead direct to the street mains. The cylinders are all steam jacketed and there are two re-heaters, one between the high pressure cylinders and the intermediate cylinders, and one between the intermediate cylinders and the low pressure cylinders. There is also an auxiliary feed water heater introduced into the exhaust pipe near the low pressure cylinder.

DIMENSIONS OF ENGINES.

Number of steam cylinders	6	
Diameter of H. P. cylinders	21	in.
" " I. P. "	33	"
" " L. P. "	60	"
Normal stroke of all pistons and plungers	49	"
Diameter of plungers	34.5	"
No. and size of H. P. piston rod	1-3½	in. dia.
" " " I. P. " "	2-3½	"
" " " L. P. " "	1-6	"
" " " Plunger "	2-3½	"
Average net area of H. P. piston	342.21	sq. in.
" " " I. P. "	842.36	"
" " " L. P. "	2805.	"
Actual average net area of plungers	926.52	"
No. and size of suction valves	216. 5-⅜	in. dia.
" " " discharge "	216. 5-⅜	"
Total area of valves in suction chamber	19.6	sq. ft.
" " " " discharge "	19.6	"

DESCRIPTION OF BOILERS.

Steam was supplied by one boiler of the Scotch marine type, having suspended within it two (2) Morrison furnaces. In front of the boiler was placed a Hawley down draft furnace and a series of super-heating pipes were placed in the combustion chamber in the rear of the boiler.

Diameter of boiler	10 feet.
Length of boiler	12 "

Size of corrugated furnace	36 in. diam. x 12 ft. long.
Number and size of tubes	140 - 2½ in diam.
Water heating surface in boiler	1340 square feet.
Heating surface in Hawley furnace (upper row not included)	62 " "
Total water heating surface in both	1402 " "
Area of upper grate	35 " "
" lower "	38 " "

CONDUCT OF THE TRIAL.

The specified head was obtained by throttling the discharge pipe in the engine room. A careful measurement was made to determine the distance between the water gauge and the city datum line, and the height of the water in the well was measured from city datum. The water pressure was determined by means of a pressure gauge, which was carefully tested both before and after the trial, and the corrections then applied to the readings obtained.

The steam consumption of the engine was obtained by weighing the condensed steam from the engine, as well as the jacket water. The feed water to the boiler was also carefully weighed. The feed water pumped to the boiler does not correspond in weight to the sum of the condensed steam and jacket water weights for the reason that steam was turned on the jackets of engines which were not running.

All blow-offs were broken and blank flanged, and all cross connections in the feed piping system, as well as other precautions usually taken in boiler testing, were carefully observed.

The coal was carefully weighed before delivering to the boilers. A sample was also taken and analyzed.

Gauges, counters, thermometers, and the length of stroke were read every thirty minutes through the test.

There being no means of measuring the water pumped except by the plunger displacement, the test was figured on this basis, deducting a certain per cent for slip and leakage around the plungers.

The valves were examined immediately after the trials, and all found to be intact and practically tight.

We give below results of the trial, and attached herewith will be found logs[*] of all the observations taken, together with steam card.

Under the conditions existing during the trials it was impossible to derive a complete heat balance, as the measured water had to run to the sewer. Such data as could be obtained, however, are given.

SUPPLEMENTARY TO TEST ON ENGINE NO. 2. SEPTEMBER 8-9, 1902.

In connection with this test a careful account was kept of the cylinder oil used. The oil used was a good grade of cylinder, mixed with a liberal amount of fine graphite. A total of 1½ gallons was used for the entire test.

A careful examination of the cylinders was made after the test, showing that the lubrication in all cylinders was good, and the cylinder walls were found to be smooth and in good shape, showing no unevenness in wear.

RESULTS.

It will be seen from the results of trials given above that the guarantee of 10 pounds evaporation per pound of combustible has been fulfilled in each of the three trials, also that the capacity of each pump exceeded 20,000,000 gallons in 24 hours.

It will also be seen that in each case the duty exceeded 150,000,000 foot pounds of work per 1,000 pounds of steam.

During the various tests, careful examinations were made of the external parts of the engines, and on the completion of the tests the steam and water cylinders were opened and the interior parts carefully inspected. All parts of the engines were found to be in good condition and to fully comply with the contract specifications.

[* The long columns of figures of these logs have been omitted in this reprint of the report.—ED.]

The Henry R. Worthington Company are therefore entitled to the maximum bonus of $15,000 for each pump tested, or a total of $45,000 for the three pumps tested.

Respectfully submitted,
(Signed) Robert W. Hunt & Co.,
Per Jno. C. McMynn.
T. T. Johnston.
Henry R. Worthington,
Per F. J. Oakes.

Chicago, Nov. 10th, 1902.

Mr. John Ericson, City Engineer, Chicago:

Dear Sir — We beg to submit the following figures relative to the areas of the plungers as used in calculating the capacities and duties of the Worthington Pumps, at Central Park Pumping Station, as given in our report of Oct. 16th, 1902:

Test Engine No. 3. August 27-28, 1902.

Area of piston No. 1 side	934.678	sq. in.
" " No. 2 "	934.139	"
" one 3½-inch rod	9.62	"
Average effective area of pistons	924.89	"

Test Engine No. 1. September 3-4, 1902.

Area of piston No. 1 side	935.799	"
" " No. 2 "	937.906	"
" one 3½-inch rod	9.62	"
Average effective area of pistons	927.233	"

Test Engine No. 2. September 8-9, 1902.

Area of piston No. 1 side	937.906	"
" " No. 2 "	933.799	"
" on 3½-inch rod	9.62	"
Average effective area of pistons	927.233	"

The average of the above "effective areas" gives the figure as shown in our original report under the heading of "actual average net area of plungers."

We trust the above will satisfactorily explain any questions which may have arisen relative to the duties and capacities.

Respectfully submitted,
(Signed) Robert W. Hunt & Co.

TEST ENGINE NO. 3.

CENTRAL PARK PUMPING STATION, AUGUST 27-28, 1902.

RESULTS OF TRIAL.

Duration of test .... hours....24

AVERAGE PRESSURES.

Steam pressure at engine, by gauge	lbs	150.05
" " " corrected	"	144.45
" " low pressure jacket	"	10.13
Vacuum by gauge	inches.	26.98
Balancing pressure by gauge	lbs	78.97
Back pressure by gauge	"	12.5
Water pressure by gauge	"	52.53
" " corrected	"	52.23
" " "	feet	120.65
Height of gauge above datum	"	31.1
Water level in well below datum	"	1.14
Total head on pump	"	152.89
Steam pressure on boiler, by gauge	lbs	159.22
" " " corrected	"	154.22
Atmospheric pressure (barometer 29.45 ins.)	"	14.45
Absolute steam pressure by gauge	"	168.67

AVERAGE TEMPERATURES.

Temperature of water pumped	deg. F.	72.00
" feed water in tanks	"	102.18
" " after leaving exhaust steam heater	"	177.26
" " " live steam purifier	"	361.96
" superheated steam at boiler	"	529.77
" " " engine	"	516.91
Degrees of superheat at engine	"	154.0
Temperature of flue gases	"	459.0

COAL.

Total coal burned	lbs.	22,779.0
Per cent of moisture		.88
Dry coal burned	lbs.	22,579.0
" " per hour	"	940.7
Total ash	"	1,861.0
Per cent of ash		8.17
Total combustible	lbs.	20,718.0
Combustible per hour	"	863.25
B. T. U. per lb. of coal		14,213.
Coal burned per sq. ft. of grate per hour (upper grate)	lbs.	27.1
" " heating surface per hour	"	0.67
Combustible burned per sq. ft. of grate per hour (upper grate)	"	24.6
" " " heating surface per hour	"	0.61

FEED WATER.

Total feed water to boilers	lbs.	195,153.0
Feed water per hour	"	8,131.37
Condensed steam from engines	"	143,734.
Jacket water from engine	"	16,400.0
Total steam used by engine	"	160,134.
Per cent of jacket water		10.24

EVAPORATION.

Feed water per lb. of dry coal	lbs.	8.64
" per lb. of combustible	"	9.41
" per sq. ft. grate surface per hour	"	232.32
" per sq. ft. heating surface per hour	"	5.78
Factor of evaporation	"	1.1660
Equivalent evaporation from and at 212° F.	"	227,548.3
Boiler horse power on basis 34.5 lbs. water from and at 212° F. per hour	"	275.
Evaporation from and at 212° F. per lb. dry coal	"	10.11
" " " per lb. combustible	"	10.97
" " " per sq. ft. grate per hour	"	271.0
" " " per sq. ft. heating surface per hour	"	6.7
Total dry coal burned to evaporate steam used by engine	"	18.534

CAPACITY.

Revolutions in 24 hours		27,814.
Average revolutions per minute		19.33
" length of stroke (both sides)	inches	49.587
Plunger displacement per revolution	gals.	794.072
" " "	cu. ft	106.148
" " "	lbs.	6,613.02
" " in 24 hours	gals.	22,086 318.60
" " "	cu. ft.	2,952,400.47
" " "	lbs.	183,934,538.28
Allowance for leakage and slip (½%)	"	919,672.69
Net water pumped in 24 hours	"	133,014,865 59
" " "	gals.	21,975,885.

WORK.

Work delivered in 24 hours	ft. lbs.	27,981,142,800.
Delivered horse power		588.82
Indicated "		660.90
Steam per D. H. P. per hour	lbs.	11.32
" I. H. P. "	"	10.01
Dry coal per D. H. P. per hour	"	1.58
" I. H. P. "	"	1.42
Combustible per D. H. P. per hour	"	1.50

BRITISH THERMAL UNITS.

(In coal and steam used by engine.)

B. T. U. in coal in 24 hours (18,534 lbs. dry coal)	263.423.742.0
" steam at boiler in 24 hours above 72° F	184,810,649.4
" " " " " 72° F. after leaving superheater	197.267,953.2
B. T. U. in steam at engine throttle above 72° F	196,407,553.6
Equivalent to B. T. U. of I. H. P. in 24 hours	40,370,826.
" " D. H. P. "	35,965,125.
B. T. U. in condensed steam	1,120,938.
" jacket water	941,108.
Total B. T. U. which could be returned to boiler	2,062,046.
B. T. U. absorbed in auxiliary heater in exhaust pipe	5,893,620.
" " exhaust steam heater	14,652,087.

DUTY.

Ft. lbs. per 1,000 lbs. steam	174,735,801.
" 100 lbs. steam	17,473,580.
" 1,000,000 B. T. U. supplied by coal	106,222,545.
" 1,000,000 " " steam	151.404,917.

ANALYSIS OF COAL USED ON TEST.

Weaver's Maryland Smokeless.

Volatile matter	22.68
Fixed carbon	67.35
Moisture	.88
Ash	9.09
B. T. U	14,213

TEST ENGINE NO. 1.

CENTRAL PARK PUMPING STATION, SEPTEMBER 3-4. 1902.

RESULTS OF TRIAL.

Duration of test	Hrs.	24

AVERAGE PRESSURES.

Steam pressure at engine—by gauge	lbs.	153.9
" " " —corrected	"	147.3
" " low pressure jacket	"	10.1
Vacuum by gauge	inches	26.7
Balancing pressure by gauge	lbs.	75.8
Back pressure by gauge	"	15.1
Water pressure by gauge	"	52.72
" —corrected	"	52.42
" "	feet	121.08
Height of gauge above datum	"	31.1
Water level in well below datum	"	1.62
Total head on pump	"	153.8
Steam pressure on boiler—by gauge	lbs.	157.2
" " " —corrected	"	157.2
Atmospheric pressure—(barometer 29.44)	"	14.45
Absolute steam pressure by gauge	"	171.65

AVERAGE TEMPERATURES.

Temperature of water pumped	deg. F.	7[illegible].
" feed water in tanks	"	104.7
" " after leaving exhaust steam heater	"	179.5
" " " live steam purifier	"	359.2
" superheated steam at boiler	"	518.0
" " " engine	"	491.
Degrees of superheat at engine	"	126.7
Temperature of flue gases	"	464.7

COAL.

Total coal burned	lbs.	24,797.
Per cent of moisture		.84
Dry coal burned	lbs.	24,588.71
" " per hour	"	1,024.5
Total ash,	"	2,313.
Per cent of ash		9.3
Total combustible	lbs.	22,275.71
Combustible per hour	"	928.1
B. T. U. per lb. of coal		14,368.
Coal burned per sq. ft. of grate per hour (upper grate).	lbs.	29.2
" " heating surface per hour (upper grate)	"	0.75
Combustible burned per sq. ft. of grate " "	"	26.5
" " " heating surface per hour	"	0.66

FEED WATER.

Total feed water to boilers	lbs.	204,897.
Feed water per hour	"	8,537.4
Condensed steam from engines	"	159,216.
Jacket water from engines	"	17,974.
Total steam used by engines	"	177,190.
Per cent of jacket water (on total steam)	"	10.1

EVAPORATION.

Feed water per lb. of dry coal	lbs.	8.31
" per lb. of dry combustible	"	9.24
" per sq. ft. grate surface per hour	"	243.9
" per sq. ft. heating surface per hour	"	6.08
Factor of evaporation	"	1.157
Equivalent evaporation from and at 212° F	"	237,065.8
Boiler horse power on basis 34.5 lbs. water per hour from and at 212° F	"	286.3
Evaporation from and at 212° F. per lb. dry coal	"	9.6
" " per lb. combustible	"	10.6
" " per sq. ft. grate per hour	"	282.2
" " per sq. ft. heating surface per hour	"	7 04
Total dry coal burned to evaporate steam used by engine	"	21,322.5

CAPACITY.

Revolutions in 24 hours		27,335.
Average revolutions per minute		18.97
Average length of stroke (both sides)	inches	49.73
Plunger displacement per revolution	gals.	799.36
" " "	cu. ft.	106.84
" " "	lbs.	6,656.1
" " in 24 hours	gals.	21,850,505.
" " "	cu. ft.	2,920,471.4
" " "	lbs.	181,855,368.22
Allowance for leakage and slip (½%)	"	909,276.8
Net water pumped in 24 hours	"	180,946,091.2
" " "	gals.	21,741,253.

WORK.

Work delivered in 24 hours	ft. lbs.	27,829,508,841.
Delivered horse power		585.6
Indicated " "		674.45
Steam per D. H. P. per hour	lbs.	12.6
" I. H. P. "	"	10.9
Dry coal per D. H. P. per hour	"	1.74
" I. H. P. "	"	1.52
Combustible per D. H. P. per hour	"	1.58

BRITISH THERMAL UNITS.

(In coal and steam used by engine.)

B. T. U. in coal in 24 hours—(21,322.5 lbs.)	306,361,680.0
" steam at boiler, above 72° F.	204,424,103.
" " " after leaving superheater, above 72° F.	213,234,940.
" " engine throttle, above 72° F.	215,073,222.
Equivalent B. T. U. of I. H. P. in 24 hours	41,195,406.
" " D. H. P. "	35,768,448.
B. T. U. in condensed steam	1,949,090.
" jacket water	1,025,807.
Total B. T. U. which could be returned to boiler	2,974,897.
B. T. U. absorbed in auxiliary heater in exhaust pipe	6,146,910.
" " exhaust steam heater	15,326,295.

DUTY.

Ft. lbs. per 1,000 lbs. steam	157,060,267.
" 100 lbs. steam	15,706,026.
" 1,000,000 B. T. U. supplied by coal	90,839,564.
" 1,000,000 " " steam	136,138,875.

ANALYSIS OF COAL USED ON TEST.

Weaver's Maryland Smokeless.

Volatile matter	22.66
Moisture	.84
Fixed carbon	68.64
Ash	7.86
B. T. U.	14,368

TEST ENGINE NO. 2.

CENTRAL PARK PUMPING STATION, CHICAGO, ILL. SEPTEMBER, 8-9, 1902.—RESULTS OF TRIAL.

Duration of test	hours	24

AVERAGE PRESSURES.

Steam pressure at engine—by gauge	lbs.	151.4
" " " —corrected	"	144.8
" " low pressure jacket	"	9.8
Vacuum by gauge	inches	26.8
Balancing pressure by gauge	lbs.	80.5
Back pressure—by gauge	"	21.7
Water pressure—by gauge	"	52.64
" —corrected	"	52.34
" "	feet	120.9
Height of gauge above datum	"	31.1
Water level in well below datum	"	1.68
Total head on pump	"	153.68
Steam pressure on boiler—by gauge	lbs.	156.5
" " " —corrected	"	156.5
Atmospheric pressure (barometer 29.20°)	"	14.35
Absolute steam pressure in boilers	"	170.85

AVERAGE TEMPERATURES.

Temperature of water pumped	deg. F.	73.
" feed water in tanks	"	100.9
" " after leaving exhaust steam heater	"	175.4
" " " live steam purifier	"	362.1
" superheated steam at boiler	"	534.3
" " " engine	"	505.7
Degrees of superheat at the engine	"	142.8
Temperature of flue gases	"	450.

COAL.

Total coal burned	lbs.	25,419.
Per cent of moisture	"	.91
Dry coal burned	"	25,188.
Dry coal burned per hour	"	1,049.
Total ash	"	2,720.
Per cent of ash	"	10.7
Total combustible	"	22,468.
Combustible per hour	"	936.
B. T. U. per lb of coal	"	13,531.
Coal burned per sq. ft. of grate per hour (upper grate)	"	30.2
" " heating surface per hour	"	0.75
Combustible burned per sq. ft. of grate per hour (upper grate)	"	26.7
" " " heating surface per hour	"	0.66

FEED WATER.

Total feed water to boilers	lbs.	204,797.0
Feed water per hour	"	8,533.2
Condensed steam from engines	"	152,773.
Jacket water from engines	"	15,294.
Total steam used by engines	"	168,067.
Per cent of jacket water (on total water)	"	9.09

EVAPORATION.

Feed water per lb. of dry coal	lbs.	8.13
" " combustible	"	9.11
" per sq. ft. grate surface per hour	"	243.8
" " heating surface per hour	"	6.08
Factor of evaporation	"	1.1702
Equivalent evaporation from and at 212° F.	"	239,653.
Boiler horse power on basis 34.5 lbs. from and at 212° F. per hour	"	290.
Evaporation from and at 212° F. per lb. dry coal	"	9.51
" " " " combustible	"	10.66
" " " per sq. ft. grate per hour	"	285.
" " " " heating surface per hour	"	7.11
Total dry coal burned to evaporate steam used by engine	"	20,672.

CAPACITY.

Revolutions in 24 hours		27,038.
Average revolutions per minute		18.76
" length of stroke (both sides)	inches	49.68
Plunger displacement per revolution	gals.	797.72
" " "	cu. ft.	106.64
" " "	lbs.	6,643.67
" " in 24 hours	gals.	21,568,753.
" " "	cu. ft.	2,883,332.3
" " "	lbs.	179,631,603.5
Allowance for leakage and slip (7%)	"	1,257,421.
Net water pumped in 24 hours	"	178,374,182.
" " "	gals.	21,417,771.

WORK.

Work delivered in 24 hours	ft. lbs.	27,412,544,335.
Delivered horse power		576.8
Indicated " (average)		661.
Steam per D. H. P. per hour	lbs.	12.1
" I. H. P. "	"	10.5
Dry coal per D. H. P. per hour (20,672 lbs.)	"	1.49
" I. H. P. " "	"	1.30
Combustible per D. H. P. per hour (18,501 lbs. in 24 hours)	"	1.33

BRITISH THERMAL UNITS

(In coal and steam used by engine.)

B. T. U. in coal in 24 hours	279,712,832.0
" steam at boiler (above 72° F.)	193,999,738.
" " " after leaving superheater above 72° F.	207,364,678.
" " engine throttle above 72° F.	205,029,975.
Equivalent B. T. U. of I. H. P. in 24 hours	40,373,880.
" " D. H. P. "	35,230,944.
B. T. U. in condensed steam above 72° F.	916,738.
" jacket water above 72° F.	866,231.
Total B. T. U. which could be returned to boiler	1,782,969.
B. T. U. absorbed in auxiliary heater in exhaust pipe	5,713,856.
" " exhaust steam heater	15,257,376.

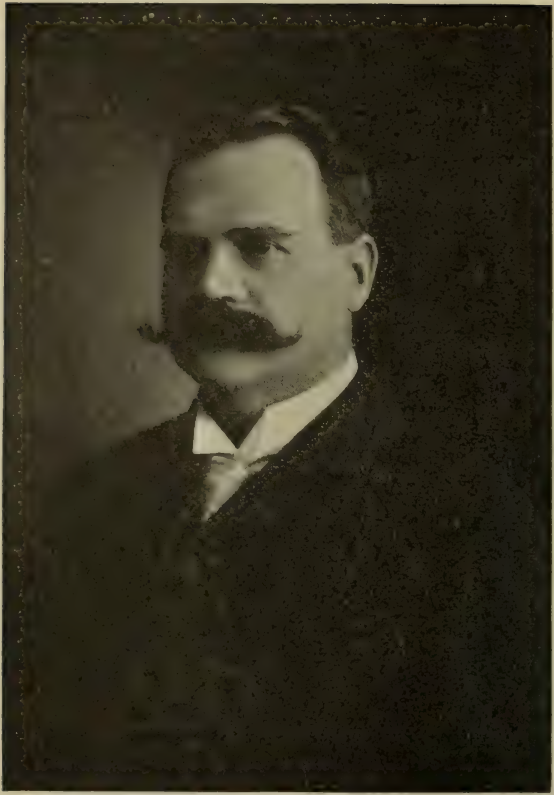
DUTY.

Ft. lbs. per 1,000 lbs. steam	163,104,857.
" 100 lbs. steam	16,310,485.
" 1,000,000 B. T. U. supplied by coal	98,002,740.
" 1,000,000 " " steam	133,700,812.

ANALYSIS OF COAL USED ON TEST.

Weaver's Maryland Smokeless.

Volatile matter	27.43
Moisture	.91
Fixed carbon	61.12
Ash	10.54
B. T. U.	13,531.



CARL BINDER.

IN MEMORIAM.

Carl Binder, a member of this Society, died February 2, 1903, after a short illness, of heart failure. He was born September 6, 1853, at Bietigheim, in Wurttemberg, Germany.

He studied engineering at the Royal Technical High School of Stuttgart, Germany; was awarded a gold medal in a competition for prizes, in 1875, and graduated in 1876. He passed both State examinations for engineers, and filled State and other positions in his native country with honor, receiving the title "Regierungs-Baumeister." In May, 1884, he came to this country, entering the employ of the Keystone Bridge Co., at Pittsburgh. He filled the position of Engineer of Bridges on the Lake Shore & Michigan Southern Railway in 1888. In 1889 he went into business in Chicago as a contracting engineer, associating himself with Mr. Seifert in 1890, under the firm name of Binder & Seifert. This partnership was dissolved in 1894, Mr. Binder continuing the business as before until the time of his death.

Mr. Binder executed a number of important contracts, including, among others, the structural steel work for the Chicago Public Library and the Machinery Hall and Horticultural Buildings at the World's Fair of 1893.

In November, 1891, Mr. Binder married Miss Selma Schneider, who survives him, with two daughters, aged ten and seven years.

Mr. Binder was taken away in the prime of manhood, while he still enjoyed and loved life, and in the midst of a successful and honorable business career. He was of modest and retiring disposition, and though on this account his circle of friends was not large, those who knew him were much attached to him and valued him highly for his many sterling qualities. He was a devoted husband and father.

CHARLES L. STROBEL,
ALBERT H. WOLF,
THEO. KANDELER,
Committee.

Chicago, April 16, 1903.

THE EXPORT OF U. S. MANUFACTURES.

The attention of the readers of the Journal of the Western Society of Engineers, and particularly of those who can avail themselves of our library, is invited to the accompanying circular letter.

The Library Committee takes pleasure in announcing that this publication—"Monthly Summary of Commerce and Finance" is received as published and kept on file in the rooms of the Western Society of Engineers, and is free to the use of those who may desire to consult it.

TREASURY DEPARTMENT, BUREAU OF STATISTICS, WASHINGTON, June 3, 1903.

DEAR SIR: Will you pardon me if I call your attention to the monograph on exportation and distribution of manufactures, and growth of the manufacturing industries of the United States, which appears in the April number of the Monthly Summary of Commerce and Finance, just issued? It is the first detailed analysis of our exportation of manufactures and their distribution ever presented by this bureau, and shows the destination of every manufactured article exported, country by country, in each year during the past decade and the total value of each manufactured article or class of articles exported, in each year, from 1790 to 1902, and incidentally the growth of manufacturing in the United States and the share which manufactures have formed of our total exports, in each year from 1790 down to date. I have felt that in its preparation, which has occupied more than a year of careful labor and study, it would not only enable each manufacturer to determine what parts of the world offer the best markets for his products, but at the same time enable the student and writer and economist to determine what sections of the world are our best customers for manufacturers and the classes of manufactures taken by each and the growth in exportation and distribution of the respective articles or classes.

Trusting that you may find it of value, and a convenience in your work, I am.

Very truly yours,

O. P. AUSTIN, Chief of Bureau.

ABSTRACT OF MINUTES OF THE SOCIETY.

REGULAR MEETING, April 1, 1903.

A regular meeting of the Society (No. 494) was held in the Society rooms, the evening of Wednesday, April 1st. The meeting was called to order about 8:30 p. m., with President Modjeski in the chair and about thirty members and guests present. The minutes of meetings held in March were read and accepted.

The Secretary presented a report from the Board of Direction, announcing the election of the following persons into membership in the Society, under their respective grades:

George P. Coleman Winona, Minn., Active
H. H. Hadsall, Chicago, transferred from Junior to Active.
Durand Churchill, Chicago, Active.
Max. L. Cunningham, Shawnee, Oklahoma Ty., Junior.
Francis T. West, Chicago, Associate.
Albert H. Westfall, Joliet, Ill., Associate.
Wm. A. Hazard, Des Moines, Iowa, Active.
Arthur Montzheimer, Joliet, Ill., Active.
John P. Ball, Chicago, Active.
Theodore C. Phillips, Brooklyn, N. Y., transferred from Junior to Active,
George E. Ellis, Chicago, Active.
Philip C. Allen, Associate.
James L. Young, Bismarck, N. D., Active.

The following list of new applications was also presented;

George M. Mayer, Chicago, Active.
B. J. Bernhard, Chicago, Junior.
Maurice N. Lovewell, Columbus, Ohio, transferred from Junior to Active.
Edward L. Cox, Chicago, Associate.
Charles A. Pratt, Chicago, Active.
Frank Neher, Chicago, Active.
James G. Warren, Milwaukee, Wis., Active.
Wm. Pierce Hoppin, Fulton, Ky., transferred from Junior to Active.

On motion of Mr. Finley, duly seconded and carried, the report from the Board of Direction was accepted.

There being no further business to come before the Society, the President introduced Prof. Chas. S. Slichter, of Madison, Wis., who gave a talk on "The Measurement of Underflow Streams in Southern California."

Discussion followed from Messrs. Burdick, Warder, Finley, Eldridge, Baldwin, Wisner, Stern, Caldwell and Slichter.

The meeting adjourned about 10 o'clock.

EXTRA MEETING. April 15, 1903.

An extra meeting of the Society (No. 495) was held in the Society rooms Wednesday evening, April 15th. The meeting was called to order about 8:30 p. m., with Past President W. H. Finley in the chair and about thirty-five members and guests present.

As there was no business to be considered by the Society, Mr. Richard McCulloch, M. W. S. E., Assistant General Manager of the Chicago City Railway, was introduced, who read his paper on "European Tramway Practice." This paper was illustrated by a number of lantern slides.

Discussion followed from Prof. Pence, of Purdue University, and Messrs. Finley, Edward Murray, Tratman, Warder, H. B. Flemming, Bernhard and McCulloch.

The meeting adjourned about 9:45.

EXTRA MEETING, April 29, 1903.

An extra meeting of the Society (No. 496) was held in the Society rooms Wednesday evening, April 29th,

The meeting was called to order at 8;20 p. m. by President Modjeski, with about forty-five members and guests present.

The President announced that the Entertainment Committee had arranged for a lecture to be given by Prof. Edwin E. Sparks, of the University of Chicago, on "Early Chicago History and Landmarks," at Kimball Hall on May 2d, for the members of the W. S. E. and their friends.

As there was no further business to come before the Society, Mr. Robert C. Smith was introduced and presented his paper on "The Borings for the Bohio Dam for the Panama Canal."

The paper was discussed by Messrs. Hatch, Geo. R. Jarvis, Armstrong, Tratman, Perkins, Trumbull, Modjeski, Warder and Smith.

The meeting adjourned about 9:45.

REGULAR MEETING, May 6, 1903.

A regular meeting of the Society (No. 498) was held in the Society rooms May 6th.

The meeting was called to order at 8:30 p. m., with Vice-President Parkhurst in the chair and about fifty members and guests present.

The minutes of the previous meetings were read and on motion of Mr. Eldridge, accepted.

The Secretary announced, on behalf of the Board of Direction, that the following persons had been elected into membership in the W. S. E.:

James C. Hopkins, Chicago, Active.
Geo. N. Mayer, Chicago, Active.
B. J. Bernhard, Chicago, Junior.
Maurice N. Lovewell, Columbus, Ohio, advanced from Junior to Active.
Edward L. Cox, Chicago, Associate.
Charles A. Pratt, Chicago, Active.
Frank Neher, Chicago, Active.
James G. Warren, Milwaukee, Wis., Active.
Wm. Pierce Hoppin, Fulton, Ky., advanced from Junior to Active.

Also that the following new applications had been received :

J. Milton Willard, Chicago, Active.
Earl C Moss, Chicago, Active.
Malcolm F. Ewen, Chicago, Active.
Joseph D. Smedberg, Joliet, Ill., Junior.
Felix Wm. Boldenweck, Chicago, Junior.
Peter Junkersfeld, Chicago, Active.
James E. Ferguson, Detroit, Mich., Active.
Walter W. Seymour, Chicago, Active.
Ralph S. McCormick, Detroit, Mich., Active.

Mr. Eldridge moved that the attention of the Board of Direction be called to the matter of binding the proceedings of the Society for those members who desire to have them bound, with a view of securing a special price from the binders. The motion was carried.

Mr. H. J. Slifer then presented his paper on "Railway Maintenance of Way," which was afterwards discussed by Messrs. Eldridge, Robinson, Parkhurst, Dobson, Armstrong, Bernhard, Hermanns, Warder, Springer, Jacobson and Chamberlain.

The meeting adjourned at 10:10 p. m.

EXTRA MEETING, May 20, 1903.

An extra meeting of the Society (No. 499) was held in the Society rooms Wednesday evening, May 20th. The meeting was called to order at 8:30 p. m. with Vice-President Parkhurst in the chair and about sixty-two members and guests present.

This being an extra meeting there was no business to come before the Society and Mr. W. W. Curtis was introduced, who presented a paper on "Timber-Treating Plants," the paper being illustrated by numerous lantern slides.

Discussion followed the reading of the paper from Messrs. Parkhurst, Finley, Chanute, Mayer, Loweth, E. C. Carter, Trumbull, J. S. Robinson and Curtis.

The meeting adjourned about 10:30 p. m. J. H. Warder, Secretary.

REPORT OF THE ENTERTAINMENT COMMITTEE.

An extra meeting (No. 497) of the Society was called for May 2, 1903, by the Entertainment Committee. This was "Ladies' Night" and as the attendance promised to be too great for the Society's rooms, the committee secured Kimball Hall for this occasion. Prof. E. E. Sparks, of the University of Chicago, gave a very instructive and entertaining address on "Early Chicago History and Landmarks." This was illustrated by a great number of lantern slides, of which some showed the geologic history of Chicago; others, taken from old and rare prints and drawings, presented odd views of the buildings and daily life of our city. Some very acceptable organ and piano music was given, and the evening closed with refreshments

There were about 150 ladies and gentlemen present, and all expressed themselves as highly pleased with the evening's entertainment.

W. H. BALDWIN, Chairman.

NEW BOOKS ADDED TO LIBRARY.

Art of Illumination, by Louis Bell, 1902. 8vo.
Automobiles—Self-propelled Vehicles, by Homans, 1902. 8vo.
Chemistry of Technology, by Groves and Thorpe:
    Vol. I, Fuels. Vol. II, Lighting. 8vo, cloth.
Chimney Design and Theory, by Christie. 8vo, cloth.
Compressed Air, its Production, Uses and Appliances, by Gardner D. Hiscox, 1901. 8vo, Cloth.
Designing of Draw Spans, by Wright. Parts I. and II. 8vo, cloth.
Dies, their Construction and Use, by Joseph V. Woodworth, 1902. 8vo, cloth.
Dynamometers and the Measurement of Power, by J. J. Flather, 1902. 8vo.
Electric Lighting, by Francis B. Crocker:
    Vol. 1, The Generating Plant, 1901. 8vo, cloth.
    Vol. 2, Distributing System and Lamps, 1902. 8vo, cloth.
Field Astronomy, by Comstock. 8vo, cloth.
Field Engineer, by Shunk. Leather flap, 12mo.
Formulas in Gearing, by Brown & Sharpe Mfg. Co. 8vo, cloth.
Hydraulics, by Bovey, 1895. Cloth, 8vo.
Iron Highway Bridges, construction of, by Boller.
Improvement of Rivers, by Thomas & Watt. Quarto, cloth.
Manufacture and Properties of Iron and Steel, by Campbell. 8vo, cloth.
Machine Design, by W. Cawthorne Unwin:
    Part 1, General Principles, Fastenings and Transmissive Machinery, 1901. Cloth, 12mo.
    Part 2, Chiefly on Engine Details, 1902. Cloth, 12mo.
Materials of Engineering, by Thurston, Part 1, Non-metallic Materials 1893.
    Part 2, Iron and Steel, 1894. Each, cloth, 8vo.
Mont Pelee and the Tragedy of Martinique, by Heilprin, 1903. 8vo.
Mechanical Movements, Devices and Appliances, by Hiscox. 8vo, cloth.
Practical Treatise on Gearing, by Brown & Sharpe Mfg. Co., 1902. 8vo.
Pigments, Paint and Painting, by Terry. Cloth, 12mo.
Railroad Construction, by Webb. Leather flap.
Retaining Walls, designing of, by Cain. 16mo, boards.
Rules, Tables and Data for Mechanical Engineers, by D. K. Clark, 1903. 8vo.
Shop Kinks, by Robert Grimshaw, 1898. 8vo.
Species of Wood, by Snow. Cloth, 8vo.
Statistics, by Algebraic and Graphic Methods, by Johnson. Cloth, 8vo.
Steam Turbine, by Neilson.
Steel, a Manual for Users, by Metcalf. Cloth, 12mo.
Stones for Building and Decoration, by Merrill.
Stresses in Bridge and Roof Trusses, by Burr. Cloth, 8vo.
Surcharged and Different Forms of Retaining Walls, by Tate, 1873. Boards, 16mo.
Teeth of Wheels, by Robinson, 1888. Boards, 16mo.
Water Supply, by Mason. Cloth, 8vo.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the last issue of the JOURNAL for April, 1903, we have the pleasure to report the following gifts from donors named:

EXCHANGES.

Royal Society of New South Wales, pamphlet, Journal and Proceedings, Vol. 35, 1901.
Association of Railway Supts. of Bridges and Buildings, Concord, N. H., pamphlet, Proceedings, 12th annual convention, October, 1902.
American Railway Engineering and Maintenance of Way Association, pamphlet, Bulletin No. 33, March, 1903.
League American Municipalities, John Macvicar, Sec'y, pamphlet, Proceedings, 1902.
Public Health Engineer, London, seven pamphlets:
"The Sanitary Problem from the Sewer-Gas Point of View."
"Morecambe Bay Sewerage Scheme," by H. B. Nichols.
"Sewer Construction," by Maxwell.
"Septic System of the Ocean and the Septic Tank System at Exeter," by Circumnavigator.
"Carburetted Water Gas and Carbon Monoxide Poisoning," by Cayzer, 1898.
"The Sanitation of London," by R. H. Reeves, 1902.
"The Wolverhampton Sewage Works," by Barrington, 1899.
American Society of Civil Engineers, one pamphlet, "Catalogue of the Library, Vol. 2, December, 1902."
One book, cloth, "Constitution and List of Members, 1903."
American Society of Mechanical Engineers, one pamphlet, "Constitution and List of Members, January, 1903."
New York R. R Commissioners, two vols., cloth, Report for 1902.
Armour Institute of Technology, Chicago, pamphlet, Year Book, 1902-3.
Rensselaer Polytechnic Institute, Troy, N. Y., pamphlet, "Laboratories of the Institute," 1902.
New Jersey Sanitary Association, Report 28th Annual Meeting, 1902. Pamphlet.
New York Electrical Society, "Power Plants of the Pacific Coast." Pamphlet.
Brooklyn Engineers' Club, one book, cloth, Proceedings for 1902, Vol. VII, Jan., 1903.
John Crerar Library, Chicago, pamphlet, Eighth Annual Report, 1902.
Worcester Polytechnic Institute, pamphlet, 33d Annual Catalogue, 1902-3.
Rose Polytechnic Institute, Terre Haute, Ind., 21st Annual Catalogue, 1903. Pamphlet.
Purdue University, Lafayette, Ind., pamphlet. Annual Catalogue, 1902-3, issued March, 1903.
Cornell University Register, pamphlet, January, 1903.
Cornell College Bulletin, pamphlet, Catalogue 1902-3.
Thos. S. Clarkson Memorial School of Technology, pamphlet, 1903.
University of Illinois, Champaign, Ill., pamphlet, Catalogue of University, 1902-3.
University of Michigan, pamphlet.

MISCELLANEOUS GIFTS.

C. O. Billow, M. W. S. E., an assortment of papers, pamphlets and books.
Prof. A. Marston, M. W. S. E., Ames, Iowa, pamphlet, "Report of the Paving Brick Committee of the Iowa Engineering Society, 1902."
Prof. I. O. Baker, M. W. S. E., Champaign, Ill., cloth bound volume, "Roads and Pavements," by Baker. 1903.

W. S. Bates, M. W. S. E., one cloth bound volume, "University of Kansas Geological Survey, Vol. 7, Special Report on Mineral Waters, 1902."

Engineering News, New York, "Engineering Contracts and Specifications," by J. B. Johnson. 1902. Cloth. 3d edition.

N. W. Henley & Co., New York, "Hardening, Tempering, Annealing, and Forging of Steel," by Woodworth. 1902. Cloth.

D. Van Nostrand Co., New York, "The Slide Valve," by Begtrup.

J. B. Lippincott Co., Philadelphia, "The Textile Fibres of Commerce," by Wm. I. Hannan, 1902. Cloth.

"Trades Waste—its Treatment and Utilization," by W. Naylor. 1902.

P. Blakiston's Son & Co., Philadelphia, "Chemical Technology," by Groves & Thorp. Vol. 4. 1903. Cloth.

McGraw Publishing Co., New York, "Steam Power Plants, their Design and Construction," by Meyer.

"Compressed Air,' New York, "Production, Transmission and Use of Compressed Air." 1903.

E. E. R. Tratman, one book, cloth, "Test of Metals, etc.," 1901. U. S. War Dept. pamphlet, "6th Annual Convention, Central States Water Works Association, 1902."

Prof. D. C. Jackson, University of Wisconsin, pamphlet, "The Potency of Engineering Schools and their Imperfections."

Wm. B. MacKenzie, C. E., Intercolonial Railway of Canada, "Railway Reconnoissance," by MacKenzie, 1902.

John Brunner, M. W. S. E., three pamphlets, "Timber Physics," by Fernow.
Two pamphlets, "Cement," March and May, 1903.
One book, cloth, "Digest of Physical Tests, 1896-7-8."

W. M. Camp, Chicago, one book, cloth "Notes on Track Construction and Maintenance."

Morton J. Elrod, University of Montana, pamphlet, "A Biological Reconnoissance, vicinity of Flathead Lake," 1902.

GOVERNMENT PUBLICATIONS.

Zeph. R. Forbes, Water Registrar, Brookline, Mass., Report for 1902. Pamphlet.

Otis F. Clapp, City Engineer, City of Providence, pamphlet, "Annual Report of the City Engineer of Providence, R. I., for 1902."

B. E. Fernow, New York College of Forestry, Cornell, pamphlet, "Fifth Annual Report of New York State College of Forestry of Cornell, January, 1903."

"Statement regarding General Policy and Practice on the College Forest, 1903."

U. S. Dept. of Agriculture, Bureau of Forestry, pamphlet, "A New Method of Turpentine Orcharding," by Chas. H. Herty.

U. S. War Dept., Washington, D. C., one book, cloth, "Annual Reports, Chief of Ordnance and Board of Ordnance and Fortifications, 1902."

Hon. James R. Mann, M. C.:
U. S. Census Reports, Twelfth Census of the United States, 1903, 10 vols., cloth.

U. S. Geological Survey, Dept. of Interior, six pamphlets:
Production of Aluminum and Bauxite in 1902. Struthers.
Production of Bromine in 1902. Struthers.
" " Arsenic " "
" " Bismuth " "
" " Antimony " "
" " Graphite " "

U. S. Coast and Geodetic Survey, one book, cloth, "Annual Reports July 1, 1901, to June 30, 1902."

Maj. W. H. Bixby, Corps of Engineers U. S. A., Detroit, pamphlet, "Statistical Report of Lake Commerce," 1902.

BOOK NOTES.

Railroad Construction. Theory and Practice. A Text Book for the Use of Students in Colleges and Technical Schools. By Walter Loring Webb, C. E., 16mo, morocco, 675 pp. and 232 illustrations. $5.00. John Wiley & Sons, New York.

An important addition to the "pocket-books" for engineers is to be found in this second edition, revised and enlarged, of Walter Loring Webb's Railroad Construction. It is primarily intended for the technical student as a text book; but will be found to contain much data and information in detail that will be of great use to the engineer in practice,

The book's usefulness for field work is much enhanced by the convenient form in which it is issued, the former "octavo" size having been found to very much limit its use. It is probable that the price of the present form will have a somewhat similar effect. The book contains the usual tables; and in addition thereto more complete logarithmic ones than are to be found in the field books. The tables for tangents, external distances, and long chords for a one-degree curve are limited in their practical use, in that the functions are given for only each ten degrees of curvature.

The multiform-compound-curve system is exemplified, the use of this curve being prevalent on many railroads of this country for transition purposes, the simplicity of this system being a great recommendation for its use: and, as the author states, although the method is not theoretically exact, it is demonstrable that the differences are so small that they may be safely neglected.

The chapter on earthwork is very complete; including form of excavations and embankments, earthwork surveys, computation of volume, computation of haul by the use of the mass diagram, elements of the cost of earthwork, blasting, etc.

In his treatment of railroad devices, the author does not attempt an extended discussion of them all; but limits himself to typical examples: The purpose being to teach principles and furnish a guide for proper methods of investigation.

A chapter each is devoted to the subject of trestles, tunnels, culverts and minor bridges, ballast, ties and other forms of rail support, rails, rail-fastenings, switches and crossings, miscellaneous structures and buildings, yards and terminals, block signalling, rolling stock, locomotives, cars, train brakes, train resistance, and cost of railroads.

Part II is devoted to railroad economics, and is treated much in detail. A study of this subject as presented by Mr. Webb cannot but be of great benefit to the locating engineer, the relation of distance, grade and curvature as affecting operation being succinctly presented. A chapter on the improvement of old lines will be of especial interest to the young engineer.

The work will be appreciated by many engineers, as well as students of present-day railroad engineering. H. H. J.

Notes on Track Construction and Maintenance. By W. M. Camp, editor of the Railway Review and Mem. Am. Soc. C. E. Published by the author, Auburn Park, Chicago. Cloth, pp. 1,214, including index; 600 illustrations. Price $3.00.

Although track construction and maintenance is an important feature in railway engineering work, there is very little literature upon the subject. There are, of course, numerous articles which appear in the engineering papers, but these treat of individual matters and details, and not of the subject as a whole. In this comprehensive volume may be found up-to-date information on almost every subject included within the scope of the title. If the information is at times a good deal detailed, or if much space is given to minor matters and at the cost of space for others perhaps more important, still the very fact of the limited amount of literature available on these subjects makes one chary of criticism. There are defects, naturally, but taken as a whole the book is a good one and a welcome addition to technical literature.

The first few chapters discuss general track construction: I, Track foundation (roadbed, ditches, culverts, etc.); II, Track materials; III, Track laying; IV, Ballasting. Chapter V, on Curves, discusses simple, compound and transition curves, curve elevation, etc. Chapter VI is devoted to switching arrangements, turnouts, frogs and switches, switchstands and lamps, and interlocking protection of switches. Chapter VII discusses the work of Track Maintenance, surfacing and lining, renewing ties and rails, detailing, and the work of oiling dusty track in summer and removing snow in winter.

Chapter VIII is on Double Tracking; Chapter IX on Track Tools, and Chapter X on Work Train Methods in Maintenance Work, Wrecking and Snow Fighting.

Chapter XI covers a great variety of matters which are not included in the preceding. Fencing for cattle, or snow protection and cattle guards, bridge floors and bumping posts, signboards and signals, the purchasing and handling of ties and disposition of old ties is followed by several pages of valuable matter on tie treatment. Metal ties are also considered. Many other miscellaneous matters are gathered into this chapter.

Chapter XII takes up the subject of organization of the department relating to "Track" in its manifold necessities. The position and duties of the roadmaster, foremen, section men and watchmen are carefully considered. Forms for reports covering the administoation of this department, to secure better results, are shown.

A supplemental chapter takes up other and additional matter, as tile drainage, material yards, tree planting, track elevation and depression in cities, metal ties in Europe, etc., etc., with some tables desirable to have in such a volume.

A very complete Index completes this comprehensive work, of which a good deal originally appeared in serial form, in which form it attracted much attention from many who were interested in this part of Railroading.

Dies, their Construction and Use, for the Modern Working of Sheet Metals. By Jos. V. Woodworth. 6 x 9 inches, pp. 384, and 500 engravings. New York, N. W. Henley & Co. $3.00.

The credit of forming thin metal plates into various shapes by means of dies is due to Yankee ingenuity and skill. To many people it would be hard to comprehend the transformation of a thin piece of sheet copper or brass into a cylinder, closed at one end, suitable for a shell for ammunition, and yet more strange and varied forms are now made, which depend primarily on the ductility of the metal manipulated, which permits it to "flow" from one form into another under pressure, and when properly guided by the dies—and secondarily, the shape, etc., of these dies and the corresponding punches.

The book treats of this subject with many illustrations of various forms of dies. The presses, or machines to operate the dies, are also shown. These are of various sizes—from those small enough to be operated by hand, to large, massive machines driven by power and capable of applying a pressure of many tons. The proper form of the dies and punches is somewhat complicated in most cases, and the design of these needs a careful study of what has been done, coupled with the exercise of much judgment.

But a study of this book and the many forms shown therein should be of much value to those interested in this line of manufacture.

Besides the shape of the several parts of the dies being shown, instruction is also given how the dies are to be made and hardened—a feature of value to the tool maker.

A copious index completes the work. W.

Hardening, Tempering, Annealing and Forging of Steel. By Jos. V. Woodworth. New York, 1903. Norman W. Henley & Co. Cloth, 6x9 inches, pp. 288, 201 engravings. Price $2.50.

This is a practical book, for the use particularly of artisans and mechanics, but also is of value to foremen and superintendents of shops.

The author discusses the material steel of various kinds and for many uses. Beginning with its selection and treatment, annealing is then considered, of which various methods are described to obtain the desired result. In connection with this is the annealing of malleable iron castings as germane to this subject. The heating and cooling of steel when being worked is an important matter, and illustrations are given freely of various forms of heating-furnaces adapted to a great variety of work. These use gas or oil, and permit a close regulation of the temperature to which the steel is subjected, which is a matter of great importance. There are shown also some ingenious automatic machines for heating and tempering a great number of pieces all of the same size and character, such as sections of knives for reaping machines.

The proper hardening of steel receives due attention, and the merits of water, brine, oil, etc., as a hardening material, is laid down.

The manipulation of special tools, as taps, dies, reamers, etc., which are costly to make, is well considered by the author, who also shows the temperature and "temper-color" for hardening various kinds of steel tools, and strongly urges that means be employed for determining the temperature within close limits for heating, hardening, and tempering each special class of tools, that the best results may be obtained.

Case-hardening, which means the formation of a thin, hard surface on otherwise softer iron or steel articles to withstand usage, naturally follows the subject of hardening. In this process use is made of a mixture of carbonaceous material, as bone charcoal, charred leather, etc., and cyanide of potash. There are illustrations of the furnaces used for this work.

Special cutting tools—as milling cutters, etc., is fully treated, with many illustrations, as also the handling of small tools when being forged, machined or hardened, and the straightening, when necessary, of such as are distorted.

The subject of grinding the edges of various forms of cutters, milling tools, etc., is shown with a profusion of illustrations, which make this part of the book of much value.

A copious index completes the book. W.

Chemical Technology, Vol. IV. Electric Lighting, by A. G. Cook. Photometry, by W. J. Dibden. Philadelphia. P. Blakiston's Son & Co., 1903. 6¾ x 10 inches, 378 pp. 181 cuts and 10 full page plates. Cloth. Price $3 50.

The name of Groves and Thorpe conveys at once to the reader the sense that the book is of interest, and is a reliable work, though our examination of the first part of the book is somewhat disappointing, in that it describes at length many forms of electrical machinery that are now somewhat obsolete. This is but natural, however, if a little consideration be given to the fact that all matters electrical have made such wonderful advances in the very recent past. It would be almost impossible to publish any work on that most recent of sciences—electricity—that would be strictly up to date. The author, however, states very frankly in his preface that the work is intended as a resumé of the various systems—machinery, lamps, etc., used for electric lighting, and the work does possess much value as a historical review of this subject.

There are sixteen chapters in the first part which treat of Conductors, Parallel Distribution, Electro-magnetism, the Dynamos—in theory, design and regulation—Storage Batteries, Transformers, Series-distribution, Alternating Currents, theory, machinery and distribution, Lamps, incandescent and arc. There is also a chapter on Central Station Economy.

The second part of the book, by Dibden, relates to Photometry, and this is a new and valuable discussion of the subject. It is very freely illustrated, is well considered and is valuable for reference.

Many standards of light, with screens, and descriptions of apparatus are given, with instructions for operating.

This subject of measurement of such an ethereal and evanescent substance—shall we call it—as light, possesses great fascination for an investigating mind, and this treatise on Photometry should be of assistance in such a case.

A table of contents, list of illustrations, and full index, increase the value of this book. E. & W.

THE ESTABLISHMENT OF AN ENGINEERING DIRECTORY.

As one of the functions of the Western Society of Engineers is to promote a feeling of comradeship between its members, and to render assistance to them in their professional work, the Board of Direction have decided to establish what, for want of a better term, may be called an Engineering Directory. The object of this is to bring together those members who may be on the outlook for an engagement and those who desire the services of engineers. It is proposed to do this without cost to the members in the way of charges, fees, etc.

The name of the applicant for position will be kept privately by the Secretary and not given out, except as provided for in the rules, and every endeavor will be made not only to render real assistance to those members of the Western Society of Engineers who are out of employment, or who may be in search of more congenial positions, but to render such assistance in the right way.

Attention of employers of engineers, whether members or not, is also called to the exceptional value of this bureau to parties desiring engineering services of the highest order.

Rules to Govern the Conduct of this Directory.

First. Blank applications for employment will be given to any member of the Western Society of Engineers or forwarded to him on receipt of request, accompanied by a self-addressed stamped envelope.

Second. When returned to the Secretary, these applications shall be numbered for identification, and posted on a public file in the rooms of the Society. The name and address of applicant shall be kept on the detached coupon on a private file, numbered the same as the application, and will not be given out except to bona fide employers, and then only when in the judgment of the Secretary no confidence is violated in so doing.

Third. Applications from employers of engineers will be placed on a similar public file, and notifications will be sent to all applicants meeting the required conditions, or to any applicant specially designated by prospective employer.

Fourth. Applications, whether of employers or those seeking employment, shall be kept on file for the two calendar months succeeding the date of appication, and then taken off and destroyed. A brief abstract of each application, identified by number only, and stating character of position sought and salary expected, will be published in the JOURNAL. Any letters addressed to file numbers in care of the Secretary will be forwarded to destination.

Fifth. Applications may be kept on file for a longer period than two months if desired by the applicant, who shall notify the Secretary to this effect by postal card or otherwise. Applicants are also requested to notify the Secretary promptly when the application is to be taken off the file.

It is to be hoped that this arrangement of applications, etc., filed at the offices of the Society, will result in benefit to those members who are seeking a professional engagement.

BY ORDER OF THE BOARD OF DIRECTION.

J. H. WARDER, Secretary.

August 5, 1902.

ABSTRACT OF APPLICATIONS FOR EMPLOYMENT.

No. 15—March 28, 1903.

Position Desired.—Railroad work (maintenance or construction), or with contracting or manufacturing company.

Experience.—Graduate civil engineer. Resident engineer, locating engineer, now assistant engineer on maintenance of way.

No. 16—April 21, 1903.

Position Desired.—Designing bridge and structural engineer.

Experience.—A graduate of the Polytechnic School at Karlsruhe, Germany. Draughtsman for three years at Edge Moor; assistant engineer with C. Shailer Smith, one year; assistant bridge engineer C., M. & St. P. Railway, two years; consulting bridge engineer, nine years; assistant engineer of the Manhattan Elevated Railway, three and one-half years.

No. 17—April 30, 1903.

Position Desired.—Mechanical or structural draughtsman. Chicago preferred.

Experience.—Graduated from an engineering school in 1896, and since then professionally engaged on engineering work.

No. 18—June 10, 1903.

Position Desired.—In charge of railway maintenance of way and structures, with chances of promotion on proving competent.

Experience.—Graduate Rose Polytechnic Institute 1889. Draughtsman eight months at Edge Moor bridge works. Rodman, transitman and assistant engineer on railway preliminary location and construction in state of Washington for two and one-half years. Engineer M. of W. Vandalia Line eight and one-half years, and one year similar work on B. & O. R. R.

No. 19—June 24, 1903.

Position Desired.—Railroad work, maintenance or construction, or position with contracting firm.

Experience.—Technical education. Seven years' experience on location, construction and maintenance, with a large R. R. Co. At present am assistant engineer on construction.

WESTERN SOCIETY OF ENGINEERS

SECRETARY'S OFFICE, LIBRARY, READING ROOM AND MEETING ROOMS
1734-41 Monadnock Block, Chicago

LIST OF OFFICERS FOR 1903

President	RALPH MODJESKI
First Vice-President	H. W. PARKHURST
Second Vice-President	PROF. F. E. TURNEAURE
Treasurer	ANDREWS ALLEN

TRUSTEES

C. W. HOTCHKISS	Term expires January, 1904
J. W. ALVORD	Term expires January, 1905
B. E. GRANT	Term expires January, 1906

The above named officers of the Society constitute its Board of Direction

Secretary and Librarian
J. H. WARDER

COMMITTEES

On Finance—H. W. Parkhurst, Andrews Allen, Geo. A. Damon.

On Publication—C. W. Hotchkiss, T. W. Snow, E. E. R. Tratman, C. W. Armstrong, John Brunner, E. B. Ellicott, W. T. Reeves, J. W. Schaub.

On Membership—B. E. Grant, Geo. S. Rice, W. L. Abbott.

On Library—J. W. Alvord, F. E. Turneaure, B. B. Carter.

On Entertainment—W. H. Baldwin, John Ericson, A. Reichmann. Chas. F. Loweth, T. W, Snow.

MEETINGS

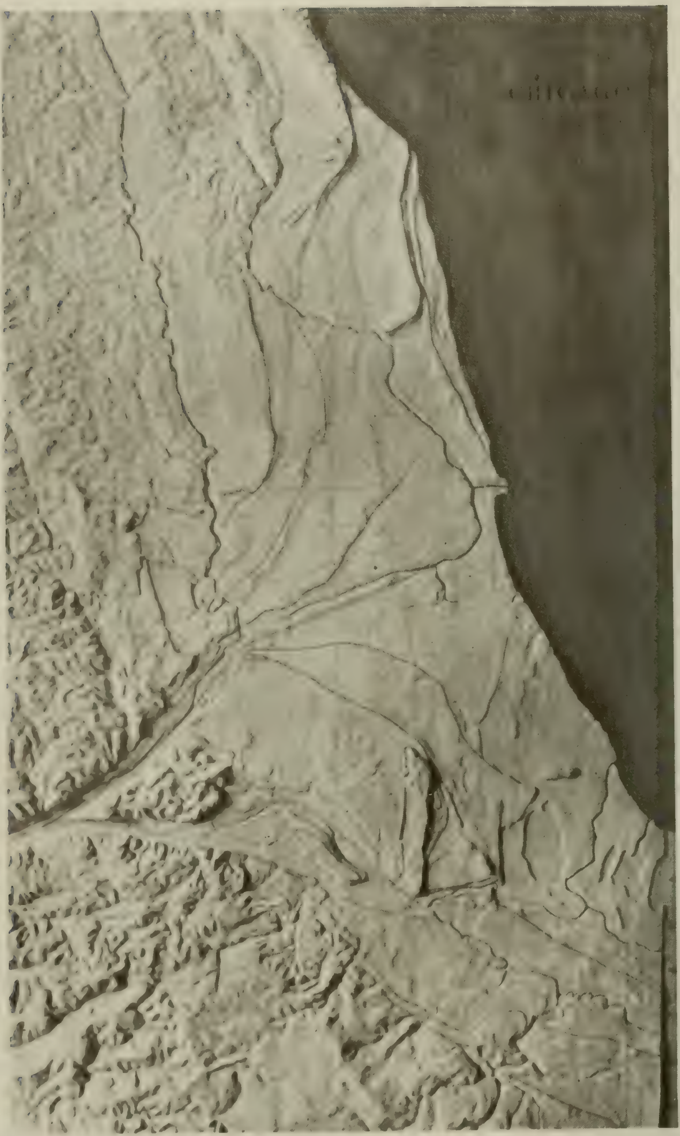
Regular Meeting—1st Wednesday evening of each month except January, July and August.

Extra Meeting—3rd Wednesday evening of each month except July and August.

Board of Direction—The Tuesday preceding the 1st Wednesday of each month.

NOTICE

From the dues of each member, $2.00 is set aside as a subscription to the JOURNAL.



THE CHICAGO PLAIN

From the Relief Map of Siebenthal at the Academy of Science, by the Courtesy of Mr. Baker, Curator.

Journal of the
Western Society of Engineers.

VOL. VIII. AUGUST, 1903. NO. 4

CLXXVI

THE BEGINNINGS OF CHICAGO

EDWIN ERLE SPARKS, PH. D.

An Illustrated Lecture, delivered before the Western Society of Engineers, May 2d, 1903.

The city of Chicago owes its existence primarily to the river bearing that name and to the fact that the river empties into the head of the most southwesterly of the Great Lakes. The history of this city, because it is situated at the mouth of one waterway and the head of another, is similar to that of other inland cities. The waterways were the ready-made highways of the interior. Up and down them passed the explorer, the missionary, the trapper, the trader, and the pioneer farmer, tracing the way for future lines of commerce. At various obstructions along these ways—perhaps the head or mouth of a river, a portage, or a natural harbor—the products of adjacent regions were collected, to be forwarded in bulk to the Atlantic seaboard. The manufactures, which were sent in return, came to these inland points for distribution. Thus what had been in turn a camping ground for the Indian, a halting place for the explorer, a post for the trader, and a rendezvous for the pioneer, became a commercial center which grew to a city. The mouth of the Chicago river was marked by nature to serve such a purpose.

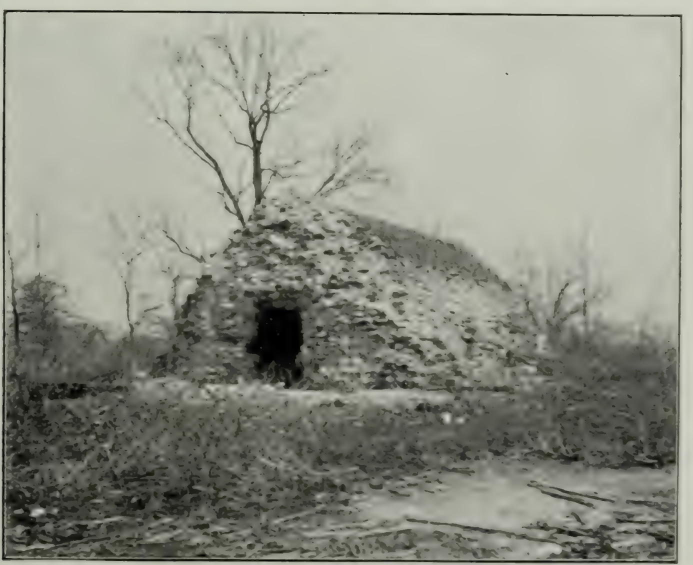
Extending in a crescent sweep about the head of Lake Michigan is a low flat plain not over fifteen miles wide, reaching from Winnetka on the north through La Grange on the west to Dyer, Indiana, on the south. Its concave side is occupied by Lake Michigan and its convex side is bounded by the great Valparaiso moraine. It was formed by the melting and retreat of the great ice cap which came down from the north in the Ice Age. At one stage the water was dammed up by the moraine, creating what is known to geologists as "Lake Chicago." At the bottom was deposited a flat plain of sand and clay which became dry land after the water had retreated to its present position to become Lake Michigan. The northern part of the plain is drained by the Chicago River and its two branches, one coming from a northern and the other from a southwestern direction.

So flat is the Chicago plain that the south branch of the river rises less than twelve miles from the mouth. Beyond the head of this branch is the outlet through which the pre-historic "Lake Chicago" was drained into the Desplaines river. The summit of this divide, between the drainage basin of the Great Lakes and that of the Mississippi valley, is the old Chicago portage, unknown and unimportant in this railway age. Here the land is only fifteen feet above the level of Lake Michigan. If the lake level had been sixteen feet higher, it would have drained into the Mississippi. The slight elevation of the watershed suggested the possibility of the present Drainage Canal.

Upon the plain described above, the city of Chicago has been built. The ground is made up of bowlders, sand, and clay—a mixture commonly known as "glacial drift." The excavation for a building in any part of the city will show the unstable character of the soil. Beneath it at varying depths lies the solid Niagara limestone which may be seen in the stone quarries in many localities just outside the limits of the plain. The bedrock is not level but has many undulations which cause the varying depths shown by borings in different parts of the city. The deepest point yet found is about one-half mile north of the junction of the two branches where the bedrock lies 124 feet below the level of Lake Michigan. The average depth is estimated to be about fifty feet. Because of the instability of the soil, few localities could have been found more unsuitable for building a city. But the demands of commerce have slight regard for topography or for good building sites. The most recent method employed by builders to overcome the inherent difficulties of the unstable plain is to sink caissons to the bedrock and fill them with concrete. We can thus imagine our great buildings standing upon gigantic stilts which rest upon the bedrock far beneath.

In such a soil and on such level ground, the river would naturally flow sluggishly and would cut a deep channel, carrying the washings to be deposited in a bar at the mouth. It would in this way form a natural harbor for lake commerce, extending two or three miles inland. However, the history of Chicago dates back to a time when a harbor for vessels of large burden was not dreamed of. It began during the days of the French missionaries, when the utility of a river as a highway was the important consideration, especially if there was only a short portage from its head to a stream flowing in the opposite direction. The Chicago river was almost ideal in this respect, since it led by its south branch to the Chicago portage and thence into the Desplaines and the Illinois, being the connecting link between the Great Lakes and the Mississippi. Like all rivers in level countries, the sluggish waters of both streams allowed navigation far up toward the portage, especially in the rainy and melting seasons. It was possible, according to the accounts of the early explorers, to take a boat at certain times of the year over the Chicago portage without unloading it.

The French explorers and the Jesuit missionaries at first reached the Mississippi by Green Bay and the Wisconsin river. But they soon learned in returning to come up the Illinois to the Kankakee and thence to cross the portage to the St. Joseph river, now in Michigan, which empties into the southeast bend of Lake Michigan. At a later time they found the still shorter way by the Chicago river and portage. No satisfactory evidence has been left to show when this route was first used. Marquette and Joliet may have passed this way on their return journey from the Illinois Indians to the mission at Green Bay in 1673. La Salle and Tonty used the Chicago route before 1680. La Salle spent a part of the winter of 1682 in the first house built by white men at the portage. The following year he headed a report: "Du Portage de Checagou, 4 Juin, 1683." When the easy route by the "Garlic river," as the stream was sometimes called because of the foul-smelling wild plant growing on its banks, became fully

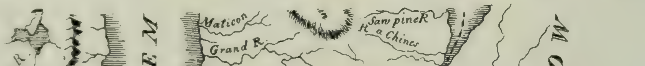


The Last of the French Fort Chartres.

known, it was one of the principal thoroughfares of the French during their prolonged journeys through the Illinois country.

Permanent French settlement, however, approached Illinois not by the Chicago portage, which the Jesuits and explorers had used, but came up the Mississippi after the founding of New Orleans. The French villages of Kaskaskia, Cahokia, and others which were founded in Illinois, soon fell into decay because of the advance of the conquering English and Americans. Even the stronghold of Fort Chartres, built to protect these villages, was torn down by the invaders to obtain building stone. Only the ruins of a powder magazine remain to show where the fort once stood.

After the French had been driven out of the Mississippi valley, the Chicago portage lay in obscurity for nearly forty years, until the onward march of the American people across the continent brought waterways and portages again into prominence. It was the policy of the United States government to plant forts along the front line of people to protect them and to increase the sales of the public lands. These forts were erected on the highways of commerce where protection was most needed. Among the sites occupied in the middle West may be named the point where the French Fort Duquesne and the English Fort Pitt once stood, now occupied by the city of Pittsburg; Fort McIntosh, where Beaver, Pennsylvania, now stands; Fort Harmer, at the mouth of the Muskingum; Fort Washington, at the mouth of the Miami, near which Cincinnati, Ohio, is now located; Fort Industry, at the



Morse's Map (1796) Showing Reservations Made by Treaty of Greenville.

mouth of the Maumee, about which Toledo, Ohio, grew; Fort Renault, now Detroit; Fort Wayne, still bearing the name, and Fort Mackinac, which is now surrounded by Machinaw city.

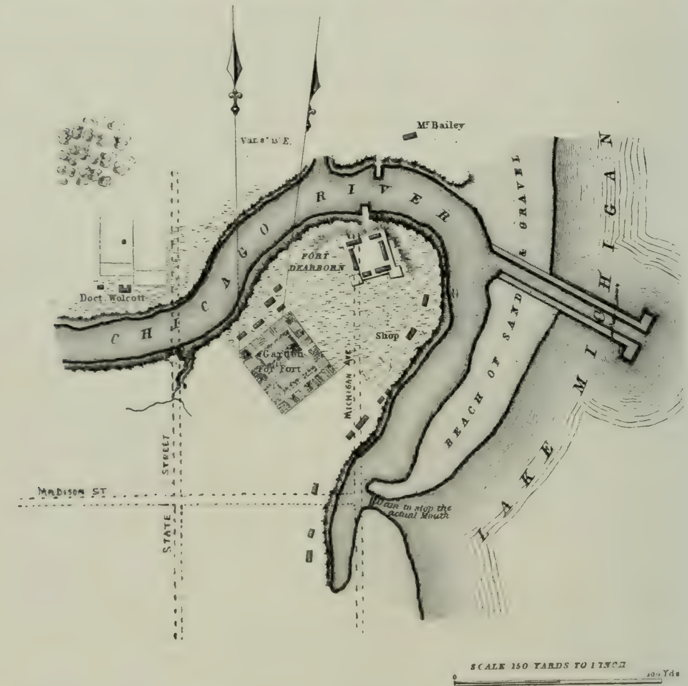
As the people advanced, the government was accustomed to quiet the Indian claims to the land by making treaties with the savages. By the treaty of Greenville in 1795, a line was drawn from east to west across what is now the state of Ohio and thence south to the Ohio river. Beyond this line the whites agreed not to make settlements, and the Indians agreed not to molest anyone living east of it. An exception was made to the first part of the bargain by the Indians giving to the United States certain reservations at important points where forts could be erected to protect traders. Among the sixteen reservations provided for by the treaty of Greenville was one for "a space six miles square at the mouth of the Chicago river where a fort formerly stood." This reference to a fort was no doubt to the traditional French fort erected in 1685 as an outpost to Fort St. Louis. It was probably nothing more than a barricaded hut.

By 1803, trade had increased along Lake Michigan to such an extent that the erection of a fort at some point on its shore was felt to be imperative. It is said that the mouth of the St. Joseph river was first contemplated; but there was no reservation at that point as demonstrated on the map made by Morse in 1796. Hence, Secretary of War Dearborn chose the reservation at the mouth of the Chicago river as a proper site. Fort Renault, at Detroit, had long been garrisoned by several companies of the First Infantry. One of these was selected to proceed to the Chicago river and to erect the proposed fort. Captain John Whistler, with some of his officers and the women, came around the lakes by boat to the mouth of the St. Joseph and thence crossed the lake by row-boat to the river. Lieutenant Swearingen marched the men by way of Fort Wayne.

One may faintly imagine the appearance of the mouth of the river when these troops arrived in August, 1803. Scrub oaks dotted the sandy shores, replaced by trees of a larger growth out toward the fertile prairies on the westward. The river flowed sluggish and silent between low-lying, sedgy banks. Evidences of Indian encampments and huts of traders could be seen on all sides. Indeed, the soldiers found a French trader, Le Mai, living in a small cabin near the mouth of the river. Near by dwelt Ouilmette (Wilmette), a half-breed Indian. Before the snows of winter covered the drifting sands, the soldiers and artificers had constructed two blockhouses, quarters for the officers and barracks for the privates, and had surrounded the whole by a high connecting stockade with a second lower palisade outside.

A subway was dug through the sand to the river to supply the fort with water in case of a siege. Near the fort was built the log house or "factory," as such adjuncts to forts were called, where the government trader exchanged his stores for skins brought in by the savages and private traders.

Not only were the general surroundings of the mouth of the river different from those of the present day. The river itself has been so changed in its course that a map is necessary to show it as the troops found it. A sand bar had accumulated across the mouth, possibly caused by that mysterious current in Lake Michigan which deposits bars on the north side of obstructions on the west shore. The bar had pushed the mouth as far south as the Madison street of the present city. This is well illustrated on a government map issued when the first proposition to convert the river into a harbor was being consideed by Congress. In the bend of the stream the fort was located. The drifting sand had made a kind of hillock or high ground at this point.



Mouth of the Chicago River in 1830 with Proposed Improvements.

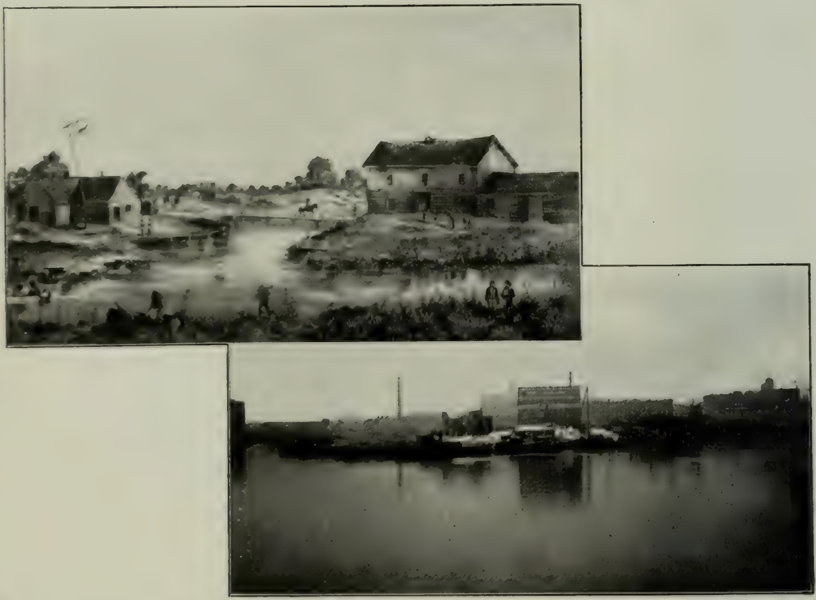
Between 1803 and 1812, the history of Fort Dearborn, as the fort gradually became known through compliment to the Secretary of War who established it, is almost a blank. There was always one company stationed here, but it must have been a dreary and monotonous life on the sands along the shore. From time to time, the "factor" made his report to the government, showing a prosperous trade. A few houses were built near the fort, that of Mr. Kinzie, just across the river, being the most prominent. The poplar trees in front of his house figure in all early sketches of Fort Dearborn, looking northward.

The year 1812 found the entire Northwest alarmed over the Indian rising under Tecumseh. Burning cabin and scalped settler warned the whites to fly to the nearest fort. Even the safety of Fort Dearborn was questioned, lying so far in the Indian country. Orders were given to the commandant to evacuate and retreat to Fort Wayne if he deemed it best to do so. Attempting to carry out these orders, the body of troops and settlers was attacked by the Indians near the present foot of Eighteenth street. Twenty-six of the fifty-four regulars were killed, together with twelve militiamen, two women and twelve children. Five more regulars, it is said, were put to death after surrender. The prisoners were then distributed among the various tribes for service. Eventually nearly all were ransomed or made their escape. For many years

The Fort Dearborn Massacre Monument—1812.

a tree known as the "massacre tree" stood near the lake and presumably near the scene of the attack on the women in the wagons. It has been replaced by a spirited group in bronze representing the rescue of Mrs. Helm by a friendly Indian, Black Partridge.

At the close of the war of 1812, the fort was rebuilt on the same site, but of different design. One block house was now felt to be sufficient. Settlers and traders gradually reoccupied their old quarters. The fearful experience of the massacre was never repeated. So peaceful were the savages that in 1823 the troops were withdrawn from Fort Dearborn to garrison posts farther west. However, in 1828, owing to the uneasiness of the Winnebago Indians, a company of regulars came up from St. Louis to reoccupy the old fort. The commanding officer was annoyed to find that the sand bar across the mouth of the river prevented him getting his supply boats into a place of safety from the storms on the treacherous lake front. He employed his men in digging a temporary channel through the bar—a prophecy of the later Chicago harbor; but the currents soon filled it up after the troops were withdrawn.



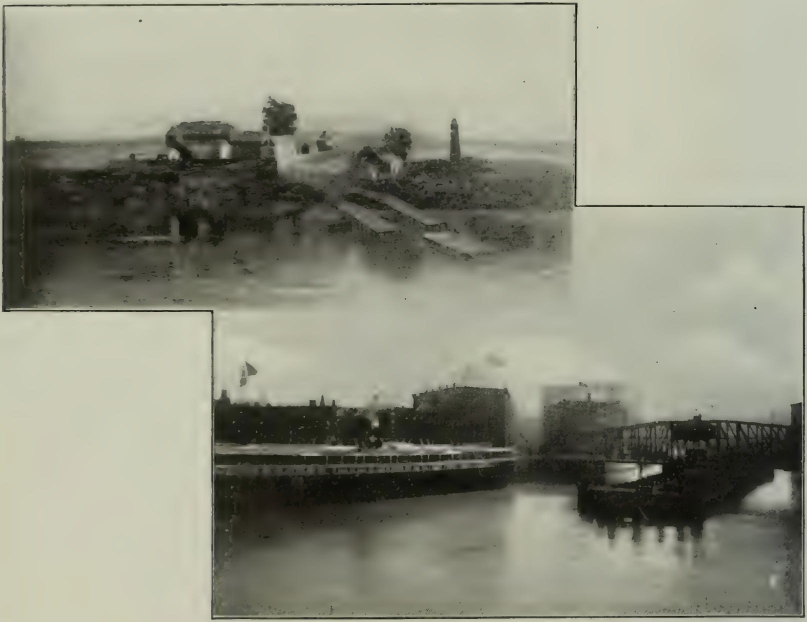
1823.—Wolf's Point, Junction of the Two Branches of the Chicago River.—1903.

In 1832, the Black Hawk war brought Gen. Scott and a large body of troops to rendezvous at the deserted Fort Dearborn. Once more the attention of Congress was called to the fact that vessels on Lake Michigan could not approach a fort which had been built to protect that body of water. Shipping must lie in the offing and discharge their cargoes by lighters. Various reports from engineers connected with the troops stationed at the fort had called attention to the same obstacle and also to the ease with which the mouth of the river might be converted into a harbor. It needed only two parallel piers out into the lake and dredging between them. No other point in the vicinity offered such possibilities. The value of the property destroyed in one season by the storms on that portion of the lake, it was declared, would go far toward making a harbor. Frequently auctions were held to dispose of the cargo, of unlucky vessels caught on the unprotected shore.

Such arguments brought from Congress in 1833 the first appropriation for straightening, deepening, and widening the Chicago river and converting it into a magnificent harbor. These appropriations were small at first, aggregating only $486,000 in nearly forty years; but were increased from time to time with the increased demands of trade until they have now passed the four million dollar point for the Chicago river and harbor alone. It is interesting to note that almost contemporaneous with the first appropriation, an enterprising trader killed and packed meat for shipment to Detroit instead of sending the cattle and hogs on foot, as had been the practice. About the same time, small elevators began to appear on the banks of the river. Grain was hauled to them in wagons from the prairies and lifted by rope and bucket to the top of the building, to run through chutes on the other side to the hold of a waiting vessel.

Fort Dearborn, near the mouth of the stream, formed one ot the centers of growth of the embryo city; the junction of the two branches, commonly known as "Wolf's Point," became another. A sketch made at the latter place in 1832 shows on the left the Wentworth tavern or trading house, and on the right the Miller house, which was also used as tavern and residence. Between them ran a log bridge across the north branch of the river. Only by comparing the scene with a modern photograph taken from the same standpoint is the change in the river and surroundings appreciable. Passing down the main stream to the right, one reaches a point on the bank opposite to that once occupied by the old fort and beholds a similar transformation. Where the rope ferry was once poled across the river, a great bridge now swings noiselessly to allow magnificent vessels to pass to docks beyond. Wharves line the shore where rushes formerly flourished in the swampy margins. The sand between the fort and the river has been dredged away to allow great floating hotels to lie at dock and await the coming of passengers. A large part of the site of the old fort is now under the Chicago river.

The lake traffic, which gave the first impetus to modern Chicago, increased enormously between 1830 and 1870. The appearance of steam vessels and the harbor improvements were largely responsible for this growth. The exact time of the coming of the first steamer is in dispute, although it must have been near 1830. At the end of 1836, it was recorded that 212 vessels had been able to get inside the river. In 1854, there were forty-six vessels plying regularly between Chicago and other ports. In 1871, more than twelve thousand vessels entered and cleared from the Chicago harbor.



The Past and Present of Fort Dearborn.

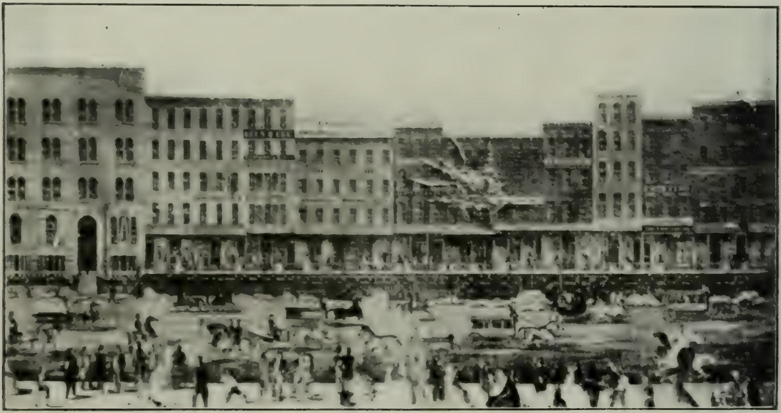
About 1830 railways, instead of canals, were advocated in the United States to connect navigable waterways. Few imagined that the railways could ever supplant the canals. A railway from the head of Lake Michigan to the Mississippi or even to the Rock river was for many years a Chicago vision. By 1848, it had been realized to some extent. The problem of conveying lead from the mines at Galena to the lake caused that city to be made the proposed western terminus. The locomotive "Pioneer," now preserved in the Field Columbian Museum, was brought to Chicago by steamer and was put to work on the few miles of strap iron laid on stringers placed end to end on piling driven into the wet prairie between the Chicago and the Desplaines rivers. This was the Galena & Chicago Union Railway, whose frame passenger station stood for many years just west of and across the North Branch from the present Northwestern station on Wells street.

By the middle of the century, the rival railways between Lake Erie and Lake Michigan, the one constructed through "Central" Michigan and the other through "Southern" Michigan, rounded the head of the lake and came into the city simultaneously. The Michigan Central and the Illinois Central came along the lake front on piling driven into the water, which carried them as far north as the foot of the present Randolph street. Between this piling and the beach, now Michigan Avenue, pleasure boats were sailed and rowed, giving the people of Chicago the use of a lake front which they have not since known. The railroads soon began to fill in the lake front, compelling the public to go beyond them in a park made by artificial means. Michigan avenue, formerely the beach of the lake, is now far inland, and the mouth of the river at the foot of Madison street exists only in tradition. Terminal yards and tall buildings occupy that part of the former site of Fort Dearborn which has not been dredged away in straightening the river. The old mouth is now a part of the new Lake Front park.

After the final evacuation of the fort, the property was put in the care of the engineer in charge of the river improvements. The reservation of six miles square made by the treaty of Greenville was a transaction with the Indians and was distinct from the United States reservation for the fort. The latter, amounting to about seventy-five acres, lay in the shape of a triangle having its apex at the fort. The base line crossed diagonally from the river near the foot of Dearborn street to the lake shore near the foot of Madison street. Under the law of 1819, which gave permission to the Secretary of War to dispose of military sites no longer needed, that official yielded to petitions from the citizens of Chicago and in 1839 divided the reservation into town lots to be sold at auction. Certain portions were reserved for public use. One of these became Dearborn park and is now occupied by the Chicago Public Library.

The fort reservation will account for only a small portion of the land occupied by the city of Chicago. The remainder of the site, lying along the river and both branches, was included in the 290,000 acres of land given by the national government to construct a canal over the Chicago-Desplaines portage. The streets, much as they are to-day, were laid off at right angles to each other across this proposed town site and the lots were sold at auction in 1830 for the benefit of the canal fund. Certain reservations were made for school purposes as well as a square for a court house. The latter ground is now occupied by the county and city buildings. At the sale, the lots along the south branch near the junction brought the highest price. The average price of all the lots was about three hundred dollars. The site of the present Sherman House brought forty dollars.

Much of the ill repute of Chicago in early days can be traced to the topography of the city. Water would not drain naturally from the low plain on which it was built. Cellars were almost impossible. Deluded purchasers found their lots under water.



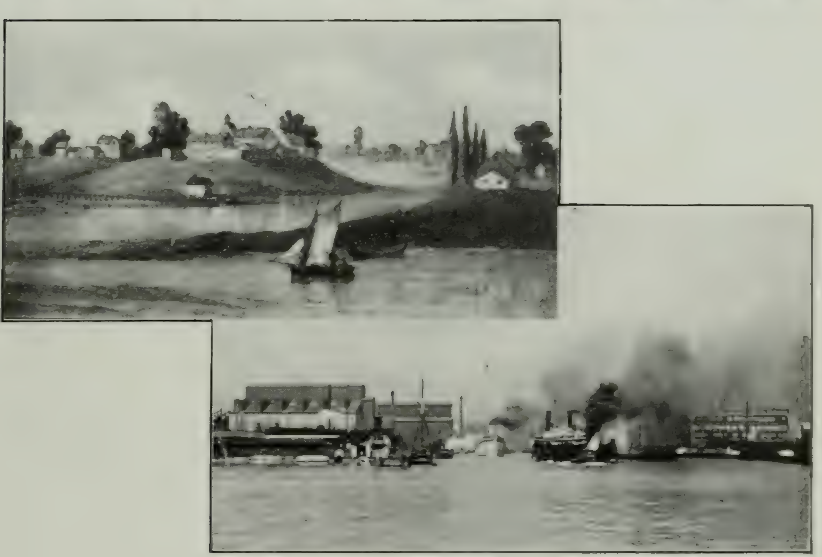
Raising the Grade of Chicago—About 1857. (From an old painting owned by Chicago Historical Society.)

Between 1855 and 1860, the grade of the entire city was raised, in some places more than ten feet. An old painting in the Chicago Historical Society's building shows the comical appearance presented by the city during this period of elevation. Entire rows of buildings rested temporarily upon blocks and jack-screws. Pavements were on different levels. The conditions of things must have conduced to sobriety since the late return home of the typical club man would have been an impossibility. The streets were filled to the new level and macadamized, instead of remaining paved with the old warped planks, which bespattered the pedestrian when a vehicle chanced to pass.

About this time, the little court house, which had done service since 1837 in the public square on the corner of Washington and

Clark streets, was replaced by a two-story stone building, to which was added a third story in due time. A lawn both at the front and back of the building afforded space for public meetings. The leading statesmen of the day graced the rostrum of the old court house steps.

The beginnings of Chicago may well close with her re-baptism in the fire of 1871. Without this blessing in disguise, it would have taken years to clean out the unsightly buildings due to the growth of the city from a frontier post. The easiest way to be rid of having to wear the clothing which one has outgrown is to burn it. Wooden pavements and frame buildings are stages of development. Chicago was done with both in the business district at one direful stroke. Only those who passed through the experience of the fire know its horrors. Only those who study a map of the "burned district" realize the space which it swept over.



1823—The Mouth of the Chicago River—*1903*

The chief problem the Chicago of today must deal with is the river. How to provide for inter-urban movement with water traffic across the principal streets has claimed the attention of engineers and experts. Few other cities face the same problem. Generally the river or harbor is to be found at one side of the city proper, or it is not so long and narrow as the one which penetrates into the very heart of Chicago. How essential the river was to the founding and the growth of the city it has been the endeavor of the foregoing pages to show. Without the river, there never would have been a Chicago. Can the prosperity of the city continue without the free use of the river for commerce? We have tried nearly every conceivable manner of crossing that stream and yet not interfering with traffic. We have crawled under it in tunnels. We have gone around it in belt lines. We have made bridges that turn, that open, that lift, that slide—anything to reconcile land and water traffic.

The history of Chicago falls naturally into three periods. The French occupancy two hundred years ago, interesting though it is, has no real connection with the modern city. The second stage, that of Fort Dearborn and the troops, which covered nearly thirty years, is only remotely connected with the modern commercial center. Industrial Chicago began with the opening of the harbor in 1833. Yet the building of the fort marked the beginning of continuous government under the United States. The stars and stripes, once raised on the staff near the middle of the fort, have floated over the city to this day. The protecting hand of the United States government, represented in the troops a century ago, in the land given for digging the old canal, and in the appropriations for the improvement of the harbor, has never been withdrawn. Counting the building of the fort as the real beginning of Chicago, the centennial will occur in 1903, to be appropriately celebrated during the last week in September.

No city in the United States can excel Chicago in the picturesqueness of her past. No city has had such a succession of varied and striking types. Above her busy streets and lofty buildings pass in historic shade the Jesuit, the trapper, the trader, the pioneer, the soldier, the land speculator, the promoter—each contributing his unconscious part to the making of an American city. The canal, which Joliet wished to cut across the Chicago portage but to which La Salle objected because the stage of water would make it serviceable during only a small portion of the year, was realized nearly two centuries later by the Illinois and Michigan canal. It has now been practically abandoned and superseded by a parallel artificial waterway designed for a ship canal.

That this service will ever be rendered by the Drainage Canal is unlikely because three great trans-continental lines of railways traverse the length of the portage. An electric trolley has been added as if to make a prophecy of the future. Where the Jesuit and his *donnes*' once dragged their sledges by head bands and straps, where the *coureur du bois* tied his bright-colored sash about his embroidered hunting shirt and set afresh his pudding-bag cap before bending to the burden of his boat, giant locomotives now drag mile-long freight trains or whirl portable hotels over the old Chicago portage.

Some day when all this is materialized on a commemorative column or historic arch, when it stands in enduring pageantry on a memorial bridge, Chicago will mean more to one class of its citizens than a place to make a fortune and to another than a place of securing daily bread. Civic as well as national pride rests most securely on veneration for the past.

CLXXVII.

THE BORINGS FOR THE BOHIO DAM FOR THE PANAMA CANAL.

By R. C. Smith, M. W. S. E.

Read April 29, 1903.

In making the borings to determine the best location for the dam which is to maintain the summit level of the Atlantic end of the Panama Canal, some rather difficult work was encountered. The results obtained are of vital importance to those having in charge the design of the dam, showing as they do a much more unfavorable site for a high dam than the data secured by the French engineers seemed to indicate.

At this time when the different phases of the Panama Canal, and the difficulties in the way of its construction are being so generally studied and discussed, a brief description of the method of making these borings, the difficulties encountered, and the results obtained may be of some particular interest.

The plans for a Panama Canal with locks, both by the French engineers and later by the Isthmian Canal Commission appointed by the United States government, call for a high dam about fourteen miles from the Atlantic terminus to maintain the summit level of the canal. Several factors combine to locate this dam at, or just above the village of Bohio:

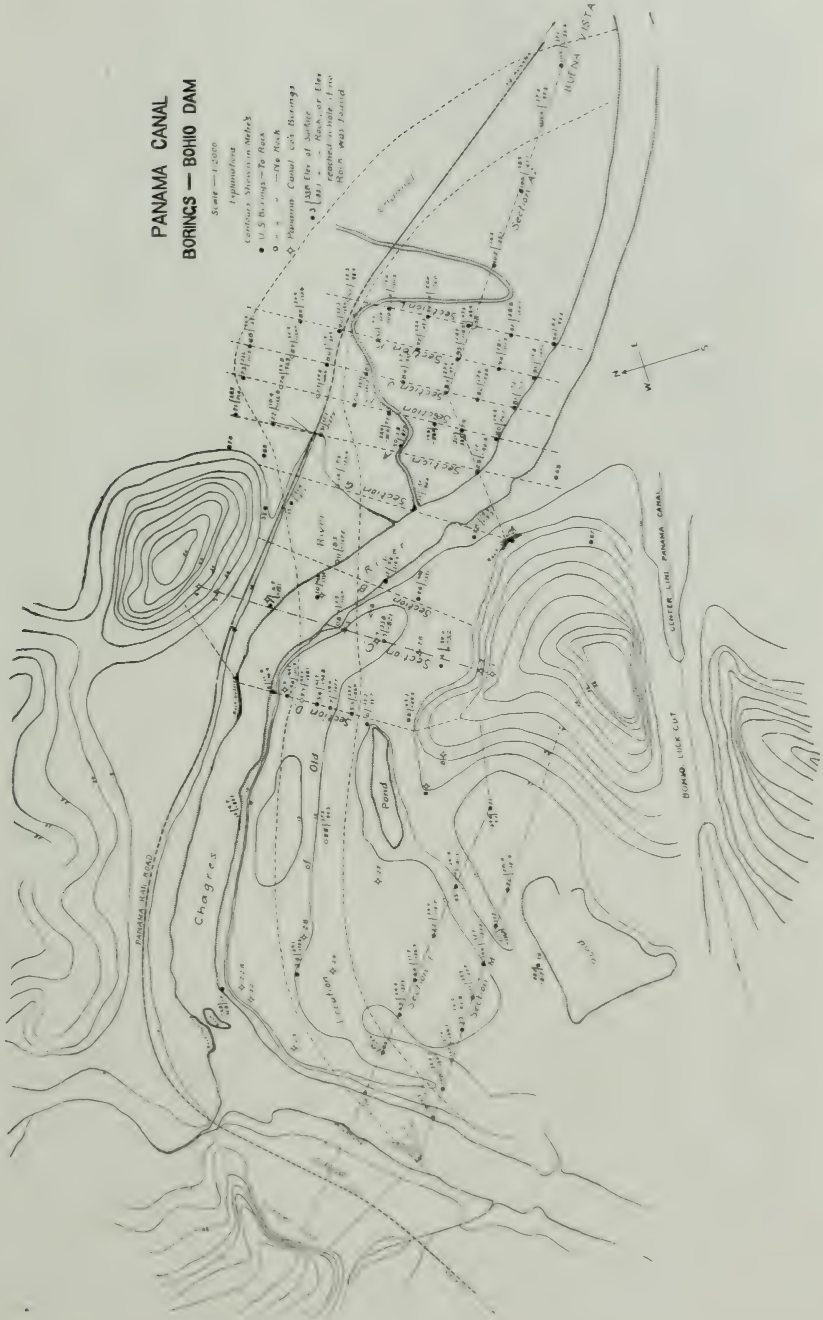
First, the valley of the Chagres river becomes very narrow for several hundred feet of its course in this vicinity. The hills which enclose the valley approach to within 1300 feet of each other at their 100-foot contours and being of rock formation furnish ideal abutments for a dam.

Second, an ideal site for a spillway exists two miles west of this place, where there is a ridge about seventy feet in height above sea level, separating the waters of the Gigante river, a tributary of the Chagres, from the waters of the latter as it passes into the swamp regions below Bohio.

Third, the lower down the valley the dam is located the greater will be the area of the artificial lake formed.

Fourth, in the investigations carried on by the French, no suitable site for the dam has been found above this section of the Chagres valley.

The French engineers, after digging six or eight test pits on the


PANAMA CANAL
BORINGS — BOHIO DAM
Scale — 1:2000
Explanations
Contours Shown in Metres
● U.S. Borings — To Rock
○ " " — No Rock
✧ Panama Canal Co's Borings
● 3 {35.0 Elev of Surface
88.1 " " Rock, or Elev reached in hole if no Rock was found
Channel
BUENA VISTA
Section A
Section B
Section C
Section D
Section G
River
Old River
Chagres
Pond
PANAMA RAIL ROAD
CENTER LINE PANAMA CANAL
BOHIO LOCK CUT
Location
N
S
E
W

hill sides, and drilling a number of holes in the valley and river bed above Bohio, selected as a site for their dam a line across the valley at its narrowest point and about half a mile above the village. On this line the summit of the ridge on the right bank of the river approaches to within 300 or 400 feet of the water, while on the left side of the river the summit of the ridge is about 800 feet away.

The borings made by the French in this vicinity, while few if any of them in the center of the valley went to rock, showed a compact clay, or compact clay sand and fine gravel, impervious to water even under considerable head. The elevation decided on for the base of their dam at its lowest point was 26 feet below sea level.

In the borings made by the Isthmian Canal Commission, with possibly one or two holes excepted, no thick bed of permeable material was found above this elevation, the stratification above in almost all cases being a favorable formation for an earth dam, which was the type selected. As the investigations of the French, however, left many uncertainties as to the exact nature of the material below this elevation, and also did not locate the rock contour in the center of the valley, it was decided by the Isthmian Canal Commission to thoroughly develop the line selected by the French, and also the territory immediately above and below this line, in order that the nature of the material overlying the rock for a considerable section of the valley might be accurately known.

To secure the above information a boring party was sent to the Isthmus in January, 1900. There were 32 holes drilled by this party, all but four of which reached rock.

While these examinations did not show as favorably as desired, it was thought that the best location the region afforded had been found, and the party was withdrawn from the Isthmus early in May. However, after carefully examining the records and information secured, so many uncertainties were still found to exist that the Commission deemed it advisable to make much more extensive investigations before deciding on the site for the dam or the type to be adopted. Another boring party was therefore organized and sent to the Isthmus the following October. This party was to examine more fully the apparently favorable lines below the French dam site; also to thoroughly explore the region above this site for a water-tight layer of material from the surface to the rock, every possible effort to be made in every hole to reach rock. The results of the borings made will later be described somewhat in detail.

These borings were made with a hand outfit; one almost identical with the outfits extensively used in the surveys of the United States Board of Engineers on Deep Waterways. The method of making them is a rather unusual one in that the casing is never driven by pounding, but is worked down by turning, back and forth,

Village of Bohio and Stone Quarry, Location End of I. C. C. Dam.

by hand, and must always be kept comparatively loose. It is a method first used, so far as the writer knows, on the Croton dam surveys, a number of years ago.

On the first work done, the party making the borings consisted of a superintendent in charge, a drill foreman and an assistant drill foreman from the United States, and such native laborers as were needed, these latter being picked up in the vicinity of the work. In organizing the second party, in addition to the foreman and assistant foreman, two helpers were included from the United States. These men were all experienced drill men and bore the brunt of the work during drill operations. The native labor was cheap, both in price and quality. Aside from their ability with the machete in cutting lines through the "bush," and at which they are adepts, the men were far from being all that could be desired in the way of helpers, but by keeping a close watch over them and exercising unlimited patience we managed to get a good deal of work out of them. Four men were kept on the pump all the time to do two men's work, and other places where they were used were provided for accordingly. The best all around native helper we had invariably had an attack of "fever" and staid at home whenever an unusually heavy day's work was anticipated.

The equipment for the work consisted of a tripod derrick, having a windlass drum arrangement at the bottom, and a sheave wheel suspended at the top; a hand force pump with hose; flush joint casing and drill rods; "cross" or double edged chopping bits; an electric push battery, and such small tools as were needed in carrying on the work. In addition to the above, the second party had an additional force pump and supply of water pipe to furnish clean water for drilling without having to carry it; they also had a conical shaped tent to be set up over the derrick and supported by it, to shield the men while at work during the rainy season.

The derrick was made in the Panama Railroad Company's shops at Colon, from plans furnished by the Commission. The axle through the drum of this derrick was fitted at each end with two straight steel handles about 30 inches long, set at right angles to each other. The drum was first fitted with wheels, one rigidly attached to the axle. This is the usual way of making these derricks, the wheels serving as a support in moving. Those furnished for this work, however, were too light for the heavy work in hand, and soon gave way. As heavier wheels could not be secured without delay, and as wheels could be but little used in moving from place to place on this work, on account of the rough nature of the country, the handles were put on and proved very satisfactory. The legs of the derrick, when drilling, set on what is known as a "jack plank," which consists of two planks 2x12 inches, botled together in the form of a T. A hole was cut in the stem of this T, through which the casing and drill rods passed. The top of this "jack plank" was used as the zero point for measurements in drilling.

Line of Panama Canal Co 's Dam Right Bank of River.

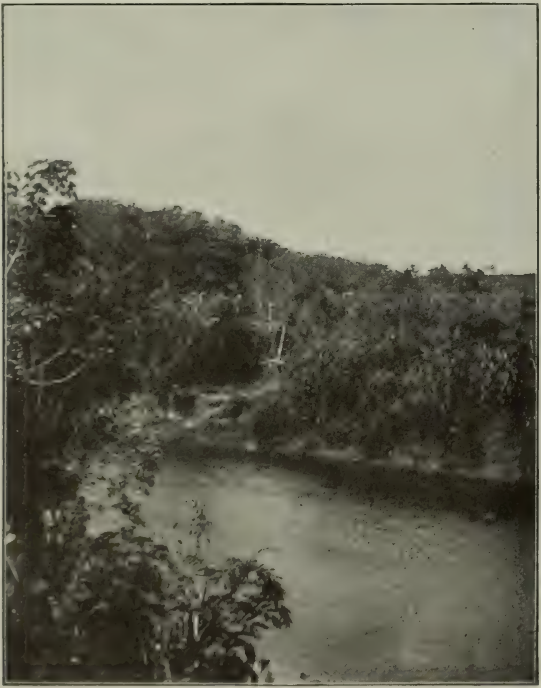
At Hole No. 8.

The casing, drill rods, chopping bits and small tools used were furnished by the Sullivan Machinery Co., of Chicago. The casing was 2½ inches inside diameter, flush-joint casing, weighing about 5.6 pounds per foot; the drill rods were the Company's standard "B" rods, 4.5 pounds per foot, with an outside diameter of $1\frac{15}{16}$ inches, allowing a clearance of a fraction over ¼-inch on all sides of the rods, inside the casing. Double-edged or cross-chopping bits were used altogether. The water swivel used was that made by the American Diamond Drill Co., of New York, a special coupling being made to fit it to the Sullivan drill rods. The pump was a double-acting hand force pump, made by the Goulds Manufacturing Co. and known as their "Challenge" Pump No. 8.

In drill operations by this method a rope passes from the drum (to which it is made fast) up over the sheave at the top of the derrick, and is attached at its other end to the sling of the water swivel. This swivel is screwed into the drill rods and is connected by means of water hose to the pump. At the bottom of the drill rods is the chopping bit, having four small holes near the cutting edges, and so placed as to throw the force of the water jet downward to the cutting edges. The pump must be kept constantly working while the bit is going ahead. Failure to observe this precaution often causes long and unnecessary delays by sand and other materials filling up in the bit when the pressure is off, necessitating pulling out the rods and cleaning the bit before the pump can again be started.

In starting a hole, if the material is of such a nature that it will not cave or fill in as soon as the bit is lifted out of it, the rods are "churned" down usually 8 or 10 feet before starting the casing. This churning of the rods is done by the drill assistants alternately pulling back on the rope carrying the drill rods and suddenly releasing it. The drop of the rods is usually 4 to 8 inches, and their weight falling this distance forces the bit into the earth; as the bit strikes, the rods are given a slight turn or twist by the drill foreman, who has hold of them with a pair of tongs; this loosens up the materal, which is then brought to the surface by the water jet.

In the case of caving material, such as sand and gravel, which fills up as soon as the bit is lifted out of it, the rods cannot be "churned" down, and must then be turned down — i. e., turned



Line of Panama Canal Co.'s Dam, Left Bank of River.

back and forth through angles of from 100° to 150°, the weight of the rods forcing them down and the jet bringing up the loosened material as before; or (as in permeable material, where a flow cannot be brought to the surface) the loosened material must be forced aside by the jet.

After a hole has been started and the rods worked down 6 or 8 feet, they are removed and the shoe piece of the casing started down. This is an ordinary piece of casing with the threads cut from one end. The casing is worked down by turning back and forth; it is never driven by pounding, and at all stages it must be kept loose enough to be shaken. The moment it begins to get too tight for this, steps must be taken to loosen it up, or the casing will stick, necessitating either abandoning the hole, or, as can often be done, working the rods down without the casing.

"Churning" Drill Rods.

In sand or gravel, or the two in combination, the flow from the pump is usually lost as soon as that material is encountered. The sinking of the casing where a flow from the pump cannot be maintained is always a slow and difficult process, and especially is this true if the permeable material lies at a considerable distance from the surface. There is no material more difficult to work through than fine running sand, and a number of holes on the Isthmus had to be abandoned on account of the thick beds of such material encountered. The casing became stuck in it, at a number of holes, and "jack screws" had to be used in starting it. In one hole the casing stuck 162 feet below the surface, and was pulled in two in trying to start it. Some sand, or sand and gravel, however, has but little tendency to grip or "seize" the casing or rods, and in a large number of such holes encountered beds of 40 to 80 feet of this material were penetrated. Progress in such material is always slow on account of its permeability. Not being able to wash up the loosened material, it must be worked to the sides of the hole, which takes much time.

When an obstruction is encountered in drilling, and through which the casing (or even the rods, perhaps) cannot be forced, unless it is quite certain that the rock ledge has been reached, dynamite must be used to open up a way. In using dynamite the hole is thoroughly washed out; the rods are then removed, and a charge of from ¼ pound to 2 or 3 pounds of 40 per cent dynamite, containing an electric exploder, is lowered into the hole by means of a pair of insulated wires properly connected with the exploder wires. The dynamite is suspended where it will be most effective, and the casing then pulled up 3 to 6 feet, depending on the amount of the charge. The dynamite is exploded by means of the electric battery at the will of the operator.

For the successful use of dynamite it is necessary to know accurately the amount of drill rods in the hole, in order that the charge can be placed where it is needed and where it will do the most good. A charge exploded a foot above or a foot below the place where it is needed often does far more harm than good. It is also necessary to know the amount of casing in the hole, in order that it can be pulled up enough before blasting to avoid danger of bursting it. To this end, the lengths of drill rods and sections of casing are entered in a note book as they are added. It is also necessary to know the combined length of drill rods in the hole, in order to determine the elevations at which the various strata occur.

It often happens, as in hard, stiff clay or in hard-pan, that the material is so tough that the casing will not shave it down or be worked into it; in such case the rods are worked ahead 6 or 8 feet, and a string of dynamite several feet in length put down. This is made by connecting a number of sticks of dynamite end to end, but with small sticks of wood, 12 to 18 inches long, separating them. The exploder is inserted usually in the lower stick of dynamite, the others being exploded by the concussion.

For successful operations by this method of drilling, an unlimited supply of clear water is very essential. In our first experience on the Isthmus, when we had but one pump, if a water supply did not exist within 40 or 50 feet of the hole, water had to be carried in buckets. In one hole it had to be carried in this way about 1,000 feet, ten laborers with two buckets each being kept busy on this hole for four days. The water as it was pumped up was often drained into a sump hole and used over again, but the use of dirty water is very objectionable in drilling, because of the dirt and trash that are constantly catching in the holes in the bit, or in the valves of the pump, causing delay to clean them. Besides, this dirty water, which has been used over and over, is often misleading in determining the nature of the material in which the bit is working.

Much trouble was experienced by the first party on the Isthmus on account of the inadequate supply of clean water. In organizing the second party, however, an extra pump and a supply of water pipe sufficient to reach an inexhaustible supply for any hole to be drilled, was included in the outfit, as already noted, and much time and labor were thereby saved and at a small initial cost.

The second party was also equipped with a supply of 3½-inch flush joint casing. It was the intention to sink this casing as far as it could be conveniently done, and then telescope the 2½-inch casing inside of it; this would cut off the friction of the earth on the smaller casing for the depth of the larger, and, it was thought, would be of advantage in the deeper and more difficult holes. But owing to its area being about twice as great as that of the smaller casing, the pump did not furnish water enough to clean the increased area of hole, especially when partly permeable strata were encountered. The larger casing, therefore, did not prove the success anticipated. The bit to fit it, however, was always used in starting a hole and worked down as long as the material did not cave, or until a permeable stratum was encountered. It was not uncommon to go 40 to 50 feet with this bit, which was a great help, giving practically the same advantage as the large casing sunk to this depth would have done.

In pulling the casing after finishing a hole, a chain and a long lever were ordinarily used to start it, the drum being used after it became loosened up all around. As has been stated, in a number of the holes drilled, the casing stuck, and jack screws had to be used to start it.

In moving from hole to hole on this work, the outfit had to be carried by the crew. The bush everywhere in this region is dense, and through it lines 12 to 14 feet in width had to be cut to get the derrick through. The cutting of these lines required an immense amount of labor, but they were kept cut so far ahead as to cause no delay in moving. The moves themselves did not require a great deal of time, as they were usually not over 300 or 400 feet in length.

On this work a very careful record of the stratification of each hole was kept. The character of each stratum, whether hard or soft, or sticky, or whether it would stand up or cave in drilling, was noted. The flow from the pump was watched and where the flow could not be maintained, or only in part, the fact was noted. In this way the permeability of each layer passed through can be told by a glance at the notes. After the hole had been finished and the rods removed, the elevation of the water in the hole was determined. In this way it was demonstrated that a close relation exists between the elevation of the water in the river and that in the holes containing any considerable amount of permeable material below the bed of the river.

Pulling Casing with Lever.

Samples were taken of the more important strata of each hole, these being bottled and properly labeled for identification. These samples were caught in a bucket as they were forced up out of the casing by the pump, care being taken that the sample secured represented as nearly as possible to obtain the nature of the material being drilled.

This section of the Isthmus is of volcanic origin. The valley of the Chagres river is very rough and dotted with innumerable round topped knolls rising from only a few feet to several hundred feet above the general plane of the valley. Rock outcrops in places on these peaks, especially in the bottoms of the ravines, but as a general thing the hillsides have weathered until a considerable thickness of soil exists.

A number of quite different kinds of rock are found in the section examined; all, however, composed of volcanic ash or other volcanic products. On one side of the Bohio lock cut, where a depth of about 90 feet has been excavated in this rock, the face of the cut shows a mass of gravel, stones and bowlders all closely cemented with volcanic ash. On the opposite side of this cut and less than 150 feet from the above, a large area of what appears at first sight to be a hard, coarse grained sandstone is exposed. When more closely examined, however, it is found to be not very hard and to contain no grit whatever. Instead, it seems to be more of the nature of a solidified mud, and was probably changed to its present condition by intense heat.

Drill Outfit. Tent Over Derrick.

A few hundred feet from the railway station at Bohio is a stone quarry, where the railway company gets out much of its stone for rubble walls and bridge abutments. This, too, appears to be a solidified mud, dark gray in color, porous, light in weight and not very hard.

The ledge encountered in drilling was, in many places, found to be quite soft on top but invariably becomes harder as the depth in it increases. A hole was never abandoned so long as material progress could be made with the drill. In several holes as much as 20 feet or more of soft rock was penetrated before the hard rock was encountered. Occasionally what appeared to be a "hard-head" was found at the surface of the ledge, but generally the bit was drilled into the ledge some distance before the hole had to be abandoned. Generally the samples of rock secured show the buried rock ledge to be similar to some outcrop in this vicinity.

Pulling Casing with "Jackscrews."

Except for a deep, buried channel, which will be described later. the rock here is covered with a thick layer of clay, or clay and sand mixed. The top of this material is usually found at elevations of not more than 10 feet above or below sea level. On top of it and extending to the surface, ordinarily 25 to 40 feet above sea level, is a blanket of yellow clay containing varying proportions of sand. This clay is very tough and stands well, as is shown by the banks of the Chagres river, the contour of which changes but little from year to year, though the banks rise at very steep angles, in many places 20 or 30 feet high from low water edge.

Moving.

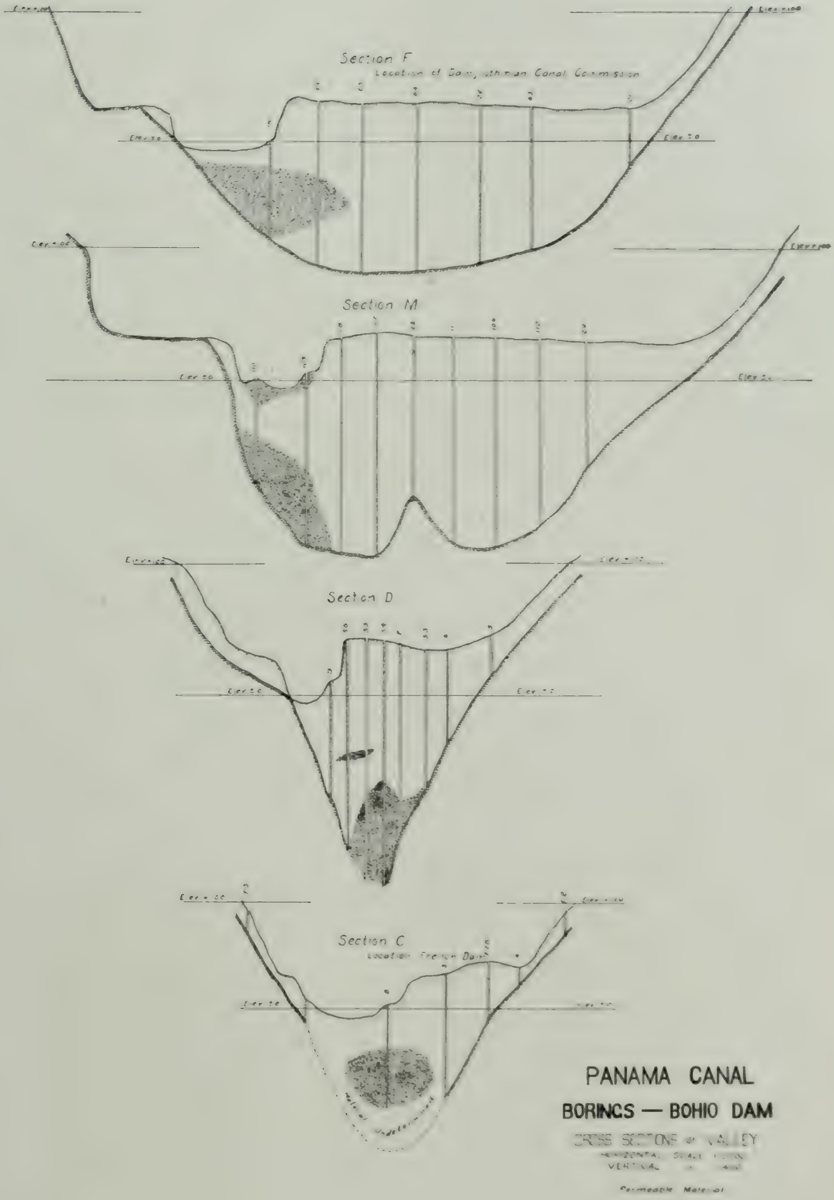
Deep underneath the surface, and extending from the upper to lower limits of the section examined, was found an old buried rock channel 300 to 500 feet in width. The limits of this channel are shown on the map in dotted lines; its course does not follow that of the present bed of the river, but crosses underneath it at the lower end of the territory examined, again in the vicinity of the French dam site, and comes back to the right bank of the river at the upper end of the section examined. Overlying the rock in this channel a bed of permeable sand and gravel 40 to 80 feet in thickness is found. Above this material and extending to the yellow clay are alternating layers of blue clay and sand, and clear sand, the sand layers usually less than a foot, (although occasionally as much as 3 or 4 feet) in thickness and always permeable. These strata are not continuous from hole to hole in fact, they might better be described as pockets of clay or sand instead of layers. It is probable that these permeable pockets are connected one with the other, and ultimately with the bed of the river, which accounts for the sudden loss of flow from the pump the instant a sand pocket is encountered. Within the limits of this old channel every hole drilled showed a large amount of permeable material, while outside these limits many of the holes were water tight from the surface to the rock. Others show occasional beds of sand or gravel, though not very thick, and none at an elevation of more than 75 feet below sea level.

The 86 holes drilled by the two parties in this vicinity could all be inclosed by the sides of a parallelogram 5,000 x 1,800 feet. These holes were located in lines across the valley, twelve in number, and are laid out and marked on the accompanying map. Four of these cross sections are platted and shown. "Section F," the line selected by the Isthmian Canal Commission for the dam, and "Section C," the line selected by the French, are of especial interest, and are described somewhat in detail.

SECTION F.

Seven holes were drilled on this line, all going to rock. Beginning at the stone quarry on the right bank of the river, rock follows the surface to the water's edge, while at the water's edge on the opposite side at hole No. 18, less than 200 feet distant, it drops to an elevation of 94 feet below sea level. Holes No. 18 and No. 66 each show an irregular stratification, though No. 18 is almost entirely in permeable material, while No. 66 shows a preponderance of such material. Holes Nos. 65, 64, 22 and 63 show a more regular stratification, with a good quality of clay and sand below the elevation of 60 feet below sea level. Hole No. 21 shows rock at 10 feet below sea level overlaid with clay and sand to the surface. Rock at the deepest place on this line was found at 127 feet below sea level, while 800 feet of the line shows rock more than 110 feet below sea level. At 300 feet down stream or below

At Hole No. 10, Bed of River.


Section F
Location of Dam, Isthmian Canal Commission
Section M
Section D
Section C
Location French Dam
Material Undetermined
PANAMA CANAL
BORINGS — BOHIO DAM
CROSS SECTIONS of VALLEY
HORIZONTAL SCALE
VERTICAL
Permeable Material

this line, and nearly parallel with it, another line, Section M, was examined. The material on this line follows closely that at Section F. Rock at the lowest point found is at 134 feet below sea level, while 1,100 feet of the line shows rock lower than 120 feet below sea level.

SECTION C.

1,800 feet above Section F, or up stream, and at about the the narrowest part of the valley, is the line selected by the French for their dam. The profile of the rock on this section, as far as determined, is shown by three holes put down by the Isthmian Canal Commission, and by four test pits dug by the French in the hill sides near the ends of the line. These pits all show rock at a high elevation and at 15 to 20 feet below the surface. Hole No. 1 put down on the right bank of the river, shows rock at 13 feet below sea level, while hole No. 8, on the left bank, had to be abandoned at 116 feet below sea level without striking rock. This was on account of the large amount of sand and gravel encountered, the material being almost entirely of this nature below the elevation of 60 feet below sea level. Hole No. 3 shows rock at 116 feet below sea level, and an irregular stratification exists at this hole, though not much permeable material was found. At hole No. 4, rock occurs at elevation 28 feet above sea level, overlaid with clay to the surface. Several holes were also drilled on this line by the French; those put down near holes Nos. 1, 3 and 4 show rock to lie practically as we found it, while two holes put down near No. 8 failed to reach rock or even to go nearly so deep as we did. At hole No. 10, which we put down in the bed of the river, 100 feet above this line, rock was found at 134 feet below sea level. Much permeable material is found here above the elevation of 105 feet below sea level, while below this elevation is found 30 feet of sand containing sufficient clay to keep a good flow from the pump in drilling. At this hole large quantities of decayed wood, bark and broken shells were brought up by the jet from a depth of over 100 feet below sea level.

About 300 feet below Section C is Section D, where the deepest and most difficult drilling was encountered. Hole No. 55 was abandoned at a depth of 180 feet, or 138 feet below sea level, and it was uncertain whether or not rock had been encountered.

At hole No. 54, rock was found at a depth of 188 feet or 146 feet below sea level. Three different attempts, requiring two weeks of the hardest kind of work, were made on this hole before finishing it. Some 80 feet of sand and gravel were found on top of the rock, and the hole had to be cased all the way to the ledge. A decayed log was encountered at a depth of 165 feet. It was soft enough to allow the bit to be worked through it, but had to be broken up with dynamite before the casing could be worked past.

No unusual features were found in any of the holes on the other sections except at hole No. 73. Here 12 feet of compact but uncemented volcanic ashes was found to overlie the rock.

Following is a tabulation of the holes drilled on this work. The depth, and the approximate amounts of impervious and permeable materials, and soft rock for each hole are given.

No. of Hole.	Depth Drilled.	Materials. Impervious.	Permeable.	Rock.
1	26.0	19.5	....	6.5
2	85.0	24.0	61.0	...
3	118.1	65.6	50.5	2.0
4	14.7	12.3	....	2.4
5	16.2	13.5	....	2.7
6	79.0	49.3	26.0	3.7
7	147.8	117.7	30.0	0.1
8	121.4	44.0	77.4	....
9	104.2	76.8	8.9	18.5
10	140.1	103.0	34.0	3.1
11	136.2	104.8	31.4	....
12	122 0	110.0	12.0	....
13	100.0	82.6	16.4	1.0
14	133.0	112.8	20.2	....
15	88.4	63.0	24.5	0.9
16	91.1	78.5	9.5	3.1
17	54.4	41.3	12.3	0.8
18	96.9	54.1	42.6	0.2
19	139.2	110.0	....	29.2
20	85.3	67.4	....	17.9
21	47.3	39.4	....	7 9
22	151 2	145.0	....	6.2
23	123.0	117.0	....	6.0
24	154.8	129.9	21.5	3.4
25	122.0	52.4	69.6	...
26	81.7	76.3	....	5.4
27	....	....	...	On Rock
28	6.2	4.6	....	1.6
29	53.8	42.3	....	11.5
30	106.5	102.0	....	4.5
31	140 0	122 0	18.0	...
32	8.5	7.6	...	0.9
53	121.3	52.4	68.7	0.2
54	187.9	104.2	83.3	0.4
55	180.6	96.1	84.5	....
56	155.4	148.0	6.4	1.0
63	119.0	115.7	....	3.3
64	162.7	159.1	2.9	0.7
65	162.3	144.5	17.7	0.1
66	157.0	103.0	52.7	1.3
67	53.0	36.4	9.4	7.2
68	115.0	93.7	....	21.3
69	57.7	43.1	12.3	2 3
70	7.3	7.3	....	....
71	81 5	54.9	25.3	1.3
72	141.2	73.3	67.1	0.8
73	145.5	75.0	70.5	....
74	125 7	82.0	43 7	....

No. of Hole.	Depth Drilled.	Material.		
		Impervious.	Permeable.	Rock.
75	136.4	96.4	40.0	..
76	149.0	134.7	7.9	6.4
77	115.4	114.6		0.8
78	110.6	94.6	15.5	0.5
79	119.6	90.4	7.2	22.0
80	89.3	59.2	13.2	16.9
81	95.0	77.7	10.8	6.5
82	95.5	73.8	6.6	15.1
83	127.7	116.0	8.4	3.3
84	103.9	100.0	3.7	0.2
85	141.3	133.5	1.7	6.1
86	161.7	137.5	24.0	0.2
87	151.1	87.9	63.2	
88	112.4	82.1	17.5	12.8
89	169.4	80.3	88.7	0.4
90	161.3	131.8	29.5	....
91	147.6	147.0	..	0.7
92	144.6	134.6	6.9	3.1
93	147.4	145.6	....	1.8
94	140.1	128.5	11.5	0.1
95	124.7	112.6	10.8	1.3
96	105.2	89.8	11.6	3.8
97	129.6	115.3	13.7	0.6
98	106.2	90.9	4.8	10.5
99	95.5	94.8	...	0.7
100	130.4	119.5	10.5	0.4
101	125.2	95.2	30.0	
102	51.8	28.4	7.9	15.5
103	92.1	68.7	12.3	11.1
104	136.7	57.0	79.7	
105	174.3	138.6	34.0	1.7
106	160.0	151.3	8.4	0.3
107	172.5	161.5	10.0	1.0
108	165.6	162.5	....	3.1
109	132.4	86.1	45.6	0.7
110	78.5	7.4	70.6	0.5
111	154.6	142.1	11.9	0.6
112	142.7	133.1	8.9	0.7

The total number of lineal feet drilled was a little over 10,000, or an average depth of 115 feet per hole. Only six holes on the work went less than fifty feet in depth, while forty went over 125 feet, and fourteen over 150 feet, the deepest hole drilled going 188 feet.

The average depth drilled per day by the first party was about fifty feet, for actual number of days worked; for the second party it was a fraction over eighty feet per day. The best single day's run was 180 feet, while 150 feet per day was averaged for twelve consecutive days work. In the holes where much sand and gravel were found, twelve to fifteen feet a day was a good average day's run for depths of over 100 feet, and many days not over six or eight feet could be drilled. On those days when the big runs were made, the holes were seldom cased below sixty or seventy feet depth, the lower material standing up well.

The data necessary to figure the cost of the work done by the first party is not at hand, but that of the second party is itemized as follows:

	Cents per foot.
Labor and superintendence	48
Traveling expenses and freight	14
Subsistence	6
Outfit	15
Total,	83

Volcanic Rock in Bohio Lock Cut.

In the above statement of cost, the outfit is considered as used up, although as a matter of fact, it was in good condition, for the most part, when the work was finished.

Not the least of the difficulties with which this second party had to contend, were the unhealthy climatic conditions, at the time they had to become acclimated. October and November are the worst months of the year on the Isthmus of Panama. It rains almost constantly day and night. The "bush," covered with the rank tropical growth, prevents all circulation of an already thick and murky atmosphere, while from stagnant pools, which everywhere abound, myriads of hungry mosquitos arise to pester the life of any man or animal so unfortunate as to come their way. And what the mosquito leaves, the “red bugs,” ticks and ants immediately take possession of. Aside from these little troubles, this party suffered much from malaria, especially during the months of November and December, no member of the party escaping. This is in marked contrast to the experience of the party sent down the winter before, during the dry and most healthful season, when not a single case of malaria developed. The heat then was greater but the climatic conditions were much better, and the health of the party was excellent.

APPENDIX.

List of Parts of Drill Outfit used on the Panama Canal Borings.

From the Sullivan Machinery Co., Chicago, Ill.

240 ft. “B” drill rods and couplings, 10-ft. lengths.
10 “ “ “ “ “ “ 5 “ “
250 ft. 2½-in. right-hand flush-joint casing, 5-ft. lengths.
1 “ “ “ “ “ 1 “ “
4 “ “ “ “ “ 2 “ “
6 “ “ “ “ “ 3 “ “
4 “ “ “ “ “ 4 “ “
1 bushing “B” rods to 2½-in. casing, right-hand, flush joint.
1 “B” hoisting swivel.
2 “B” cross chopping bits.
3 pair No. 3 Brown’s patent pipe tongs.
2 “ “ 4 “ “ “ “
2 pair No. 13 chain tongs.
1 special coupling “B” rods to American Co.’s water swivel thread.
1 10-in. Coes monkey wrench.
1 15 “ “ “ “
1 10-in. Stilson wrench.
1 14 “ “ “
1 24 “ “ “
1 15 “ steel crow bar.
1 pair sister hooks to take 1¼-in. rope.
1 single pulley block (pivot hook), 1¼-in. rope
50 ft. 1⅛-in. Manila rope.
1 hand oiler.
1 pick.
1 shovel.

2 ⅜-in. Crane chains, each 4 ft. long, with hook and ring.
1 pair combined nipper and pliers.
2 10-in. cross-cut files.
2 6-in. three-cornered files.
2 cold chisels.
1 small hand saw.
1 brace with bits ¼, ½, ⅝, ¾, ⅞ and 1-in.
6 pieces 2-in. gas pipe 4-in. long, no thread, lap weld.
6 " 1½ " " 3 " " " " " "
Used in clamping tongs to drill rods and casing.
400 ft. of insulated copper wire.
1 pair of pipe clamps for 2½-in. casing.
2 Jack Screws, 2 x 18-in.
Only the chopping bit of the following used to any great extent.
120 ft. 3½-in. right-hand, flange-joint casing, 5-ft. lengths.
1 " " " " " 1 " "
4 " " " " " 2 " "
6 " " " " " 3 " "
4 " " " " " 4 " "
1 bushing "B" rods to 3½-in. casing.
1 cross chopping bit for 3½-in. casing, connection for "B" rods.
2 pairs No. 5 Brown's patent pipe tongs.
1 pipe clamp for 3½-in. casing.

From the American Diamond Rock Drill Co., New York, N. Y.

1 1⅞-in. hoisting water swivel.

From the Gould Manufacturing Co., Seneca Falls, N. Y.

2 "Challenge" No. 8 brass-lined double acting force pumps, each fitted with 10 ft. suction hose, and globe suction basket. The discharge end of one fitted to ¾-in. water hose.
2 sections of ¾-in. 4-ply water hose, each 30 feet long, one end fitted to connect with pump, and the other end fitted with ½-in. nipple, 4 in. long.
2 sets of extra valves for pumps.
4 lbs. of Gland packing for pumps.
300 ft. wrought iron pipe 1½-in. diam.

MISCELLANEOUS.

1 25-hole electro-magnetic push battery.
1 case of 4-oz. wide mouth bottles for samples of borings.
4 balls of candle wick.
1 hank of sash cord.
1 1-gal. oil can.

1 50-ft. Chesterman metallic tape graduated feet and tenths.

1 conical tent 14 ft. diam., made with open ring 3 in. diam. at top, and fitted with ropes for guying.

1 derrick, consisting of—
  8-in. drum with 1¼-in. steel axle, and 4 30-in. straight steel handles.
  2 pieces, 3x4 in., 20 ft., } with bolt and clevis for sheave wheel.
  1 piece, 4x4 in., 20 ft., }
  1 piece, 3x4 in., 8 ft.
  2 pieces, 2x4 in., 11 ft., with steel boxes for axle of drum.

1 jack plank consisting of—
  1 piece, 2x12 in., 16 ft.
  1 piece, 2x12 in., 12 ft.
  4 ¾x5 in. bolts.

DISCUSSION.

Mr. J. N. Hatch—What was the purpose of the dam—to furnish water for the locks or to keep the water back?

Mr. Smith—The purpose of the dam was to obviate the necessity of constructing a sea level canal, the idea being to impound the waters above this dam, forming an artificial lake, at a maximum elevation of about ninety feet. This would make an artificial lake of about thirty-eight square miles area, being about sixteen miles in length.

Mr. Geo. R. Jarvis (Sullivan Machinery Co.)—I am not a member of this society, but came here to-night as a representative of the Sullivan Machinery Co., who furnished nearly all the tools for this work. I read Mr. Smith's paper with much interest, and will say that this method of drilling some six years ago was entirely new to us. When we were asked in regard to the best way of getting down to the rock we would have mentioned any other way but this. We had other ideas then as to what were the best methods of penetrating soft material to the rock, but this paper demonstrates that the hand power outfit for such purposes is an excellent one.

Mr. Smith mentions that the largest size of casing supplied—3½-inch could not be used there. I should like to ask him whether, if larger pump power had been supplied, he considers that 3½-inch casing would have been found useful.

Mr. Smith—With a stronger and larger pump and the power to operate it, the 3½-inch casing would undoubtedly have been a benefit.

Mr. Jarvis—Would the hand power have been sufficient under those circumstances?

Mr. Smith—I hardly think so. The amount of material washed up is twice as great with the larger casing, but at the same time the area between the drill rods and larger casing is about four times the area between the drill rods and smaller casing, so it cuts down the velocity of the pump fourfold instead of twofold.

Mr. Jarvis—Whether or not you use the larger casing depends upon the material, I suppose.

It may be of interest to some of the members to know that since that time we have furnished this outfit to the Deep Water Way Commission of New York, the Isthmian Canal Commission, and, if my memory serves me right, we furnished some for the United States Geological Survey in their explorations throughout the country for irrigation purposes. We have also supplied them to engineers for testing for bridge foundations. Of course where tests have to be made through rock beyond the loose materials for a considerable depth, our diamond drills are always used. We have sold four diamond drill outfits already to the United States Geological Survey; also one or two drills operated by hand power or horse power.

Another question occurs to me. Mr. Smith mentions that in a few cases, in attempting to pull the casing up, it pulled in two. How much did you lose in the whole amount of work done?

Mr. Smith—Just five feet, the break occurring at the first joint below the surface.

Mr. W. C. Armstrong—How did you keep the casing from getting tight so it would work down without being driven?

Mr. Smith—That is the secret of success in this method of drilling. It is done by working the casing back and forth. If you are working in sticky material it is necessary to pull up the casing and work it down again.

Mr. Armstrong—Then you keep the casing moving all the time?

Mr. Smith—Yes, sometimes it is necessary to pull up the casing two or three times. As soon as it begins to get tight something must be done to loosen it.

Mr. Armstrong—I would like to ask in regard to the advantage of this method over the old method involving the use of the sand pump.

Mr. Smith—The advantages in this method are—first, unless obstructions are encountered the work proceeds continuously, the material being brought to the surface by the water as fast as it is loosened up, the casing being worked down at the same time; second, the casing being always loose, but little time is lost when it becomes necessary to pull up to use dynamite; also after finishing a hole, much time is saved if it is not necessary to use jacks to pull the casing the first few feet.

Mr. Tratman—Mr. Smith has given us very full particulars of the way in which the drilling was done. I think it would be interesting if he could add to that some further particulars of the way the results were made and recorded. He mentions that "samples were taken of the more important strata of each hole, these being bottled and properly labeled for identification," etc. Of course it is of great importance to know just when you strike the different strata, at what depth, and how long they continue. I wish to ask how these observations were made of the material washed up and how he determined the depth.

Mr. Smith—You will notice in the paper that there is a picture of men churning the drill rods; you will also notice the foreman has hold of the drill rods with pipe tongs. During drill operations, from the time the hole is started until finished the foreman handles these tongs. Just as soon as he passes from one material to another (it may be the change is very slight), he can tell from the action of the bit when this change takes place. He knows the number of feet of drill rods in use. He measures from the top of the drill rods down to the jack plank, the elevation of which is known and from which the elevation of the top of the stratum encountered can be determined and is recorded, or rather, what is really done, the depth from the "jack plank" to the material is recorded and the elevations are worked up later. Soon after a different material is encountered the flow from the pump brings up samples which show the nature of the material being drilled.

Mr. Perkins—Mr. Smith speaks in his paper of finding, in one case, large quantities of decayed wood, bark and broken shells, and in another case a decayed log. I would like to ask if that is all they encountered in the way of logs, trees and stumps.

Mr. Smith—I do not remember of any holes showing logs except the two mentioned, but in a number of holes throughout this channel we found grasses, shells, bark and other evidences of organic life.

Mr. Armstrong—In connection with this subject I might mention a little experience I had out in Iowa, a few years ago.

We used for that work a drilling machine which was on the sand pump principle. Our power was a gasoline engine, 3½ horse-power, mounted on a frame and connected with the machiney by a belt. The engine made about 400 revolutions per minute, I think, and this was geared down to about 75 to 100 strokes of the drill per minute. The entire machinery was mounted on a pair of wagon trucks and hauled from one place to another as the work progressed.

I presume a great many are familiar with this sand pump method. We do not use a supply of fresh water all the time, but the same water is used over and over again and allowed to settle in a sump and flows back into the hole being drilled. The class of material we went through was clay overlying the stratified material that is usually found in coal regions; that is, shales of different kinds, fire clay, sand-stone, seams of coal, and occasionally some other harder material. About two-thirds of the aggregate distance drilled was in this stratified material, which was of the hardness of ordinary sand-stone. We drilled altogether about 6,000 feet, there being 62 holes in all, with an average depth of nearly 100 feet. The greatest depth was 150 feet. The cost per hole was about 53 cents per foot and our average progress per day was 34 feet.

Afterwards the same machine was used in making test drillings in the bed of the Mississippi river at Clinton, and there we had nothing but pure fine sand. We made about the same progress per day. We put down about 40 or 50 holes; the deepest one was about 82 feet. I presume, in material of this kind, a force pump would have been more efficient than the sand pump, but as we had this machine we used it in place of changing to anything else, and furthermore, we did not know, at the time of starting in, what kind of material we would encounter.

The casing was driven by pounding. The advantage of the method spoken of by Mr. Smith lies in the fact that by working the casing down by hand you do not need to stop your drilling machine. Of course we had to stop our machine, disconnect the rope and attach it to a hammer to drive our casing, which made some delayin progress. However, the machine we used proved very satisfactory, and it is specially efficient where one encounters material of different kinds. It will go through rock just as well as any other material. We used a chisel-pointed bit as that was the only form that could well be used with this outfit.

Mr. M. K. Trumbull—I wish we might get a little more detailed account from Mr. Smith of the relative merits of the line for the dam selected by the Isthmian Canal Commission and the one chosen by the French engineers.

Mr Smith—The line selected by the French is at the narrowest section of the valley, and has the advantage of being only about one-third as long as the site selected by the Isthmian Canal Commission; but it is here that the deepest part of the old channel is found with from 40 to 80 feet of permeable material immediately over the rock, and a possibility that the worst conditions are not yet known, since we are not able to determine the rock contour on a part of this line.

On the other line the rock does not lay quite so deep, not nearly so much permeable material is found, and what does occur is for the main part at a much higher elevation. Every hole put down on this line reached rock and it is probable that the worst conditions on this line are known.

As to the cost of borings in different sections of the country, and under varying conditions, a fair idea of the limits of such cost may be had from the report of the United States Board of Engineers on Deep Waterways, the cost of the borings for some divisions of which surveys being given below:

TONAWANDA-OLCOTT LINES.

Total number of feet drilled..........	9,624
Total number of holes...............	404
Average depth per hole.............	23.8 ft.
Average cost per foot...............	$0.684

HUDSON RIVER AND LAKE CHAMPLAIN LINE.

Total number of feet drilled..........	57,991
Average cost per foot...............	$0.124

LOWER HUDSON RIVER LINE.

Total number of feet drilled..........	28,965
Total number of holes..............	1,385
Average depth per hole.............	20.9 ft.
Average cost per foot...............	$0.251

EASTERN MOHAWK RIVER LINE.

Total number of feet drilled..........	55,521
Total number of holes..............	1,562
Average depth per hole.............	35.5 ft.
Average cost per foot...............	$0.540

WESTERN MOHAWK RIVER LINE.

Total number of feet drilled..........	33,711
Total number of holes..............	750
Average depth per hole.............	45.0 ft.
Average cost per foot...............	$0.703

Mr. Armstrong—Of course it depends largely on the character of the material.

Mr. Smith—Yes, very much.

Mr. Modjeski—What is the character of rock generally encountered in that locality?

Mr. Smith—The rock is a volcanic rock, not very hard. In a good many places it is nothing more than a mass of boulders—small gravel stones up to stones that weigh 400 or 500 pounds, the mass cemented with volcanic ash. This material weathers well down there, but in sections like this it would soon break down. There, however, there has been very little disintegration. The rock at the Panama railroad stone quarry is very porous, and appears to harden when exposed to the air, and it seems to last. If it were subjected to frost, that would undoubtedly prove a disadvantage. It is a rock that would not be fit for service under crushing loads.

The rock we encountered from the hills seemed to be more of the nature of the rock of the stone quarry than cemented boulders. In a number of cases, while it certainly was rock, it was not of a very different nature from the clay we passed through; at the surface of the ledge it was soft, but began to get harder as we went into it, until finally we ran into the harder rock. None of this was what we would here call hard rock.

Mr. Trumbull—I would like to ask if the elevation of the crest of the dam as proposed by the French was approximately the same as proposed by the Isthmian Canal Commission.

Mr. Smith—I do not remember the exact elevation proposed for the French dam, but it was about 65 feet. The maximum elevation is 90 feet and the minimum elevation is 85 feet above sea level for the Isthmian Canal Commission dam.

Mr. Modjeski—Would the material above the rock where it is not permeable afford a good foundation for such a dam, and is it hard enough to support the weight?

Mr. Smith—The clay from the surface to sea level is a yellow clay with varying proportions of sand, but it will be a water tight material and is very hard. The banks of the Chagres river rise, in some places, so steep that a man cannot climb them, and a comparison of maps shows very little change in the contour of these banks. Below sea level we struck the blue clay and sand. This was a stiff material as a general thing and contains sufficient clay so that, I think, under the head of the dam it will not be permeable at all.

CLXXVIII.

EXPERIMENTS AND OBSERVATIONS IN SOARING FLIGHT.

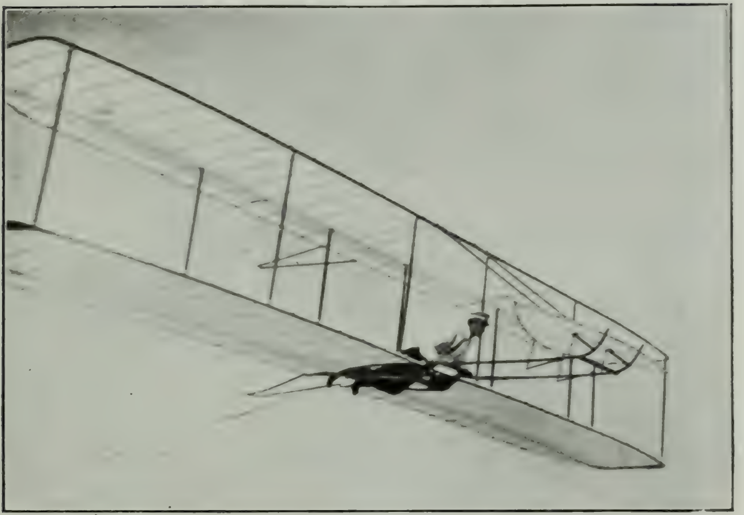
By Mr. Wilbur Wright, Dayton, Ohio.

Read June 24, 1903.

In the address which I delivered before this society in September, 1901, some account was given of the gliding experiments made by my brother, Orville Wright, and myself in the years 1900 and 1901. Afterward laboratory experiments were undertaken for the purpose of determining for ourselves the amount and direction of the pressures produced by the wind upon plane and arched surfaces exposed at various angles of incidence. The results having indicated the possibility of a gliding machine capable of much better performance than any previously built by us, we set about designing a new one for the 1902 season, and in August repaired to our old camp at the Kill Devil hills. We found that in our absence the wind had blown the sand from under the ends of our building and let them down fully two feet, so that after a rain the floor was covered with water to a depth of about twenty inches. We, therefore, proceeded to raise the building to its former level, and built a small addition to make it large enough to house the new machine.

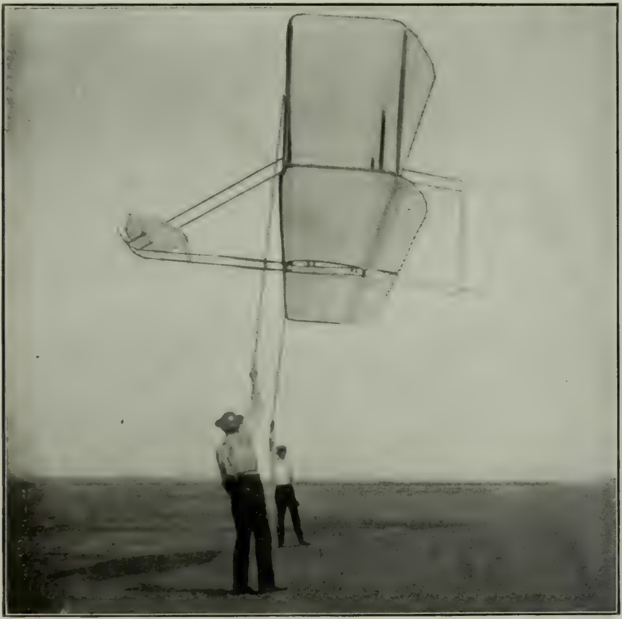
The 1902 pattern was a double deck machine having two surfaces each 32 feet from tip to tip, and 5 feet from front to rear. The total area of the main surfaces was about 305 square feet. The front rudder spread 15 square feet additional, and the vertical tail about 12 square feet, which was subsequently reduced to 6 square feet. The weight was 116½ lbs. Including the operator, the total weight was from 250 to 260 lbs. It was built to withstand hard usage, and in nearly a thousand glides was injured but once. It repeatedly withstood without damage the immense strains arising from landing at full speed in a slight hollow where only the tips of the wings touched the earth, the entire weight of machine and operator being suspended between.

The practice ground at the Kill Devil hills consists of a level plain of bare sand, from which rises a group of detached hills or mounds formed of sand heaped up by the winds. These hills are constantly changing in height and slope, according to the direction and force of the prevailing winds. The three which we use for gliding experiments are known as the Big Hill, the Little Hill and the West Hill, and have heights of 100 feet, 30 feet and 60 feet, respectively. In accordance with our custom of beginning opera-



At Close Range.

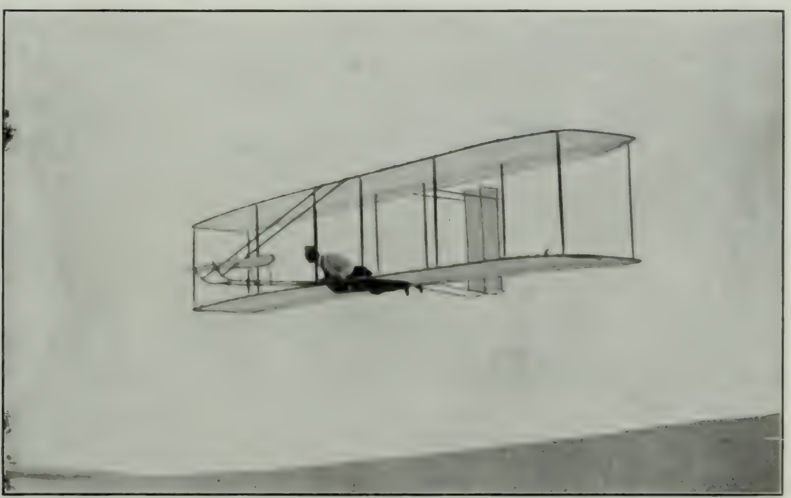
tions with the greatest possible caution, we selected the Little Hill as the field of our first experiments, and began by flying the machine as a kite. The object of this was to determine whether or not it would be capable of soaring in a wind having an upward trend of a trifle over 7 degrees, which was the slope of the hill up which the current was flowing. When I speak of soaring, I mean not only that the weight of the machine is fully sustained, but also that the direction of the pressure upon the wings is such that the propelling and the retarding forces are exactly in balance; in other words, the resultant of all the pressures is exactly vertical, and therefore without any unbalanced horizontal component. A kite is soaring when the string stands exactly vertical, this showing that there is no backward pull. The phenomenon is exhibited only when the kite is flown in a rising current of air. In principle soaring is exactly equivalent to gliding, the practical difference being that in one case the wind moves with an upward trend against a motionless surface, while in the other the surface moves with a downward trend against motionless air. The reactions are identical. The soaring of birds consists in gliding downwards through a rising current of air which has a rate of ascent equal to the bird's relative rate of descent. Testing a gliding machine as a kite on a suitable slope, with just enough wind to sustain the machine at its most favorable angle of incidence, is one of the most satisfactory methods of determining its efficiency. In soaring, the kite must fly steadily with the string vertical or a little to the front. Merely darting up to this position for an instant is not soaring. On trial we found that the machine would soar on the side of a hill having a slope of about 7 degrees, whenever the wind was of proper force to keep the angle of incidence between 4 and 8 degrees. If the wind became too strong or too weak the ropes would incline to leeward. The picture was taken when the wind was too weak for real soaring. The surfaces are inclined 4 degrees above the horizon, which is marked by the ocean level in the distance. Since the wind had an upward trend of 7 degrees, the total angle of incidence was 11 degrees, which is outside the limits specified. On steeper slopes the ropes inclined to windward quite strongly. In experimenting on this plan, it is essential that a uniform slope be found which will give the air current a rising trend just sufficient to cause the kite string to stand vertical. Then both gravity and the pull on the string, which together provide the force counteracting the wind pressure on the surfaces, are applied in a single direction. It is therefore not material what proportion of the total counteracting force is due to each of the several components, nor even what is their total amount, because the experiment is exclusively for the purpose of determining the direction of the pressure on the surfaces by observing the direction of the reaction. When the kite string inclines to windward the slope is too steep, if to leeward not steep enough. But it is not advisable to attempt to



Kite Flying.

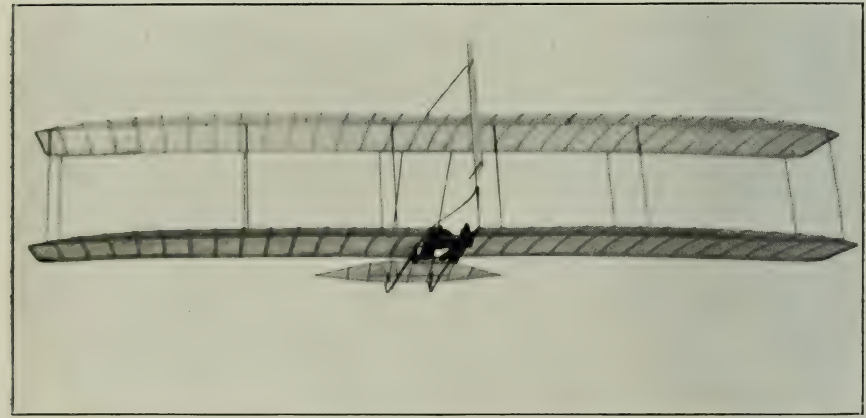
determine how much the slope varies from the proper amount by observing the angle of the string from the vertical, for when the pull of the string differs in direction from that of gravity it becomes necessary to know not only the angle but also the exact amount of the pull and the proportion which it bears to the weight of the kite. It is therefore advisable to hunt a better slope rather than attempt to make so many observations.

The kite experiments having shown that it ought to be possible to glide on the 7-degree slope, we next proceeded to try it. Although on this first day it was not considered advisable to venture upon any absolutely free flights, the machine soon demonstrated its ability to glide with this angle of descent. At a later period we made more than a hundred flights the full length of this slope and landed a short distance out on the level ground. On the second day the machine was taken to the Big Hill and regular gliding was commenced. The wind was somewhat brisk. In one flight the wind struck the machine from the left and began lifting the left wing in a decidedly alarming manner. Owing to the fact that in the new machine changes had been made in the mechanisms operating the rudders, so that the movements were exactly reversed, it was necessary to think a moment before proceeding to make the proper adjustment. But meanwhile the left wing was rising higher and higher. I therefore decided to bring the machine to the ground as quickly as possible, but in my confusion forgot the change that had been made in the front rudder and instinctively turned it the wrong way. Almost instantly it reared up as though bent on a



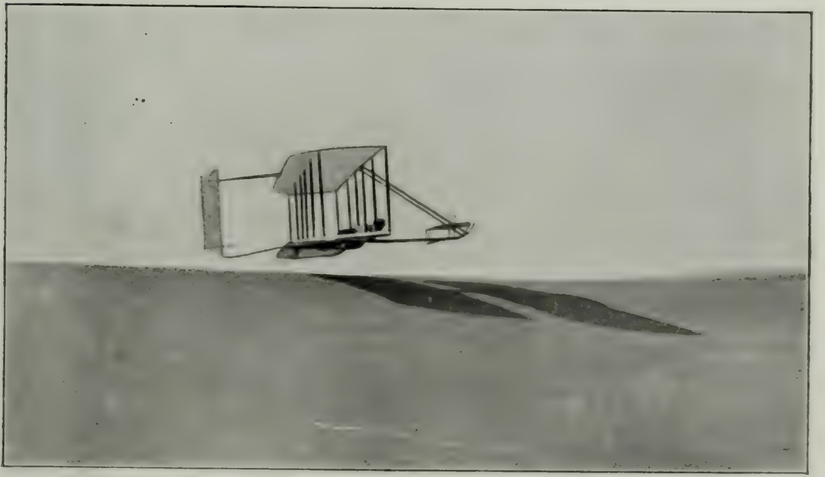
A Glide with Double Tail Machine.

mad attempt to pierce the heavens. But after a moment it seemed to perceive the folly of such an undertaking and gradually slowed up till it came almost to a stop with the front of the machine still pointing heavenward. By this time I had recovered myself and reversed the rudder to its full extent, at the same time climbing upward toward the front so as to bring my weight to bear on the part that was too high. Under this heroic treatment the machine turned downward and soon began to gather headway again. By the time the ground was reached it was under fair control, but as one wing touched first it swung around in landing and came to rest with the wind blowing in from the rear. There was no unusual shock in landing and no damage at all resulted. In several other glides there were disturbances of the lateral equilibrium more marked than we had been accustomed to experience with the former machines, and we were at a loss to know what the cause might be. The new machine had a much greater tip-to-tip dimension than our former machines; it also had a vertical tail while the earlier ones were tailless; and the wing tips were on a line with the center while the old machines had the tips drawn down like a gull's wings. The trouble might be due to either of these differences. We decided to begin alterations at the wing tips, and the next day made the necessary changes in the trussing, thus bringing the tips six inches lower than the center. For several days thereafter the weather was not suitable for gliding on account of rain, but finally the sky cleared and the machine was taken out again. As the anemometer indicated a wind velocity of more than 11 meters a second, it was thought best to make use of the Little Hill in testing the effect of the changes that



View from the Rear.

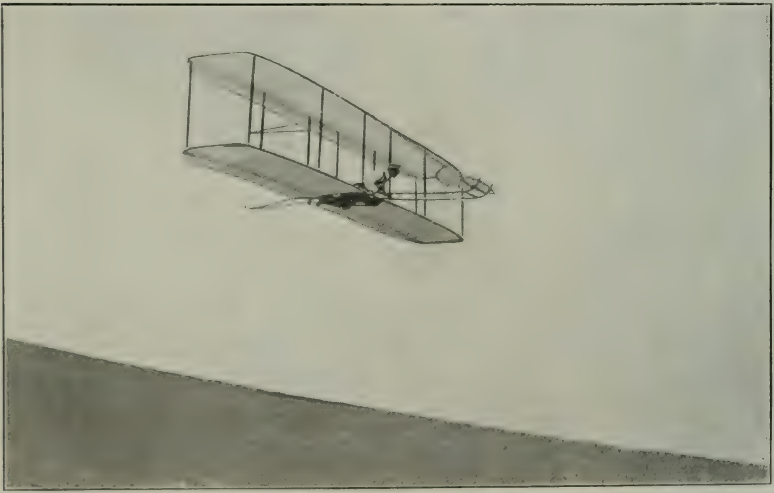
had been made. But later in the day, when the velocity fell to about nine meters a second, the Big Hill was tried again. On this day my brother Orville did most of the gliding. After a few preliminary flights to accustom himself to the new method of operating the front rudder, he felt himself ready to undertake the management of the lateral control also. Shortly afterward he started on a flight with one wing slightly higher than the other. This caused the machine to veer to the left. He waited a moment to see whether it would right itself, but finding that it did not, then decided to apply the control. At the very instant he did this, however, the right wing most unexpectedly raised much worse than before and led him to think that possibly he had made a mistake. A moment of thought was required to assure himself that he had made the right motion, and another to increase the movement. Meanwhile he had neglected the front rudder by which the fore and aft balance was maintained. The machine turned up in front more and more till it assumed a most dangerous attitude. We who were on the ground noticed this in advance of the aviator, who was thoroughly absorbed in the attempt to restore the lateral balance, but our shouts of alarm were drowned by the howling of the wind. It was only when the machine came to a stop and started backward that he at length realized the true situation. From the height of nearly thirty feet the machine sailed diagonally backward till it struck the ground. The unlucky aeronaut had time for one hasty glance behind him and the next instant found himself the center of a mass of fluttering wreckage. How he escaped injury I do not know, but afterward he was unable to show a scratch or bruise anywhere, though his clothes were torn in one place. This little misadventure which occurred almost at the very begin-



Skimming the Ground.

ning of our practice with the new machine was the only thing approaching an accident that happened during these experiments, and was the only occasion on which the machine suffered any injury. The latter was made as good as new by a few days' labor, and was not again broken in any of the many hundred glides which we subsequently made with it. By long practice the management of a flying machine should become as instinctive as the balancing movements a man unconsciously employs with every step in walking, but in the early days it is easy to make blunders. For the purpose of reducing the danger to the lowest possible point we usually kept close to the ground. Often a glide of several hundred feet would be made at a height of a few feet or even a few inches sometimes. It was the aim to avoid unnecessary risk. While the high flights were more spectacular, the low ones were fully as valuable for training purposes. Skill comes by the constant repetition of familiar feats rather than by a few over-bold attempts at feats for which the performer is yet poorly prepared.

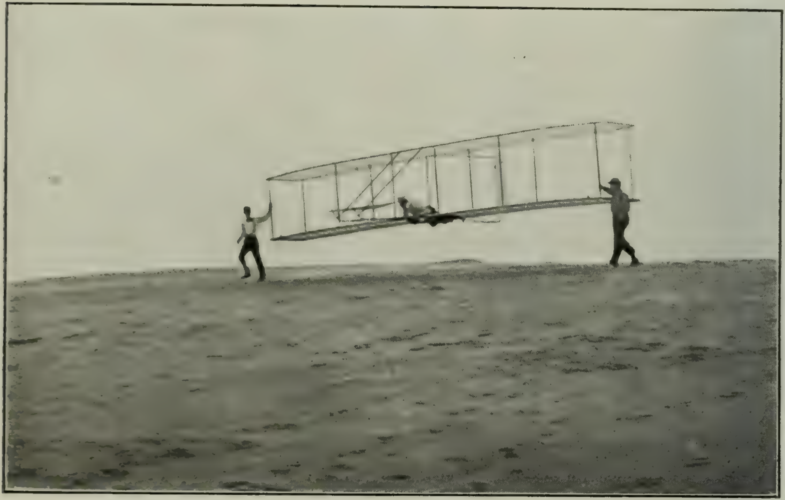
It had been noticed during the day that when a side gust struck the machine its effect was at first partly counteracted by the vertical tail, but after a time when the machine had acquired a lateral motion, the tail made matters worse instead of better. Although the change that had been made in the wing tips made some improvement, the lateral control still remained somewhat unsatisfactory. The tail was useful at times and at others was seriously in the way. It was finally concluded that the best way of overcoming the difficulty was by making the tail movable like a rudder. As originally built the fixed vertical tail or vane was double, but in changing to a movable rudder it was made single, as the smaller area was believed to be



A Good Flight.

sufficient. As reconstructed it spread a little less than six square feet. With this improvement our serious troubles ended and thereafter we devoted ourselves to the work of gaining skill by continued practice. When properly applied the means of control proved to possess a mastery over the forces tending to disturb the equilibrium. Since balancing was effected by adjustments of the surfaces, instead of by movements of weight, the controlling forces increased in power in the same ratio as the disturbing forces, when the machine was suddenly struck by a wind gust. For this reason we did not seem to experience the same difficulty in managing the machine in high winds, that Lilienthal who used a different system seems to have met. Fully half of our glides were made in winds of 10 meters a second, over 20 miles an hour. One day we stopped gliding for a moment to take an anemometer reading and found that it indicated 16.7 meters a second, 37 miles an hour. Of course such high winds require much greater readiness on the part of the operator than the low winds, since everything happens much more quickly, but otherwise the difference is not so very marked. In those machines which are controlled by the shifting of weight, the disturbing influences increase as the square of the velocity, while the controlling factor remains a constant quantity. For this reason a limit to the wind velocity which it is possible to safely encounter with such machines is soon reached, regardless of the skill of the operator. With the method we have been using the capacity of control is evidently very great. The machine seems to have reached a higher state of development than the operators. As yet we consider ourselves little more than novices in management. A thousand glides is equivalent to about four hours of steady practice, far too little to give anyone a complete mastery of the art of flying. Progress is very slow in the preliminary stages, but when once it becomes possible to undertake continuous soaring advancement should be rapid. Under special conditions it is possible that this point is not so far away as might be supposed. Since soaring is merely gliding in a rising current it would be easy to soar in front of any hill of suitable slope, whenever the wind blew with sufficient force to furnish support, provided the wind were steady. But by reason of changes in wind velocity there is more support at times than is needed, while at others there is too little, so that a considerable degree of skill, experience and sound judgment is required in order to keep the machine exactly in the rising current. So far our only attempts at soaring have been made on the Little Hill, which has a slope of only seven degrees. In a wind blowing from 11 to 16 meters a second, we frequently made glides of 8 to 15 seconds' duration with very little forward motion. As we kept within five or six feet of the ground, a momentary lessening of the wind speed, or a slight error in management, was sufficient to bring about a landing in a short time. The wind had too little rising trend to make soaring easy. The buzzards themselves were balked when they attempted to soar on this hill, as we observed more than once. It would be well within the power of the machine to soar on the Big Hill, which has steeper slopes, but we have not felt that our few hours of practice is sufficient to justify ambitious attempts too hastily. Before trying to rise to any dangerous height a man ought to know that in an emergency his mind and muscles will work by instinct rather than by conscious effort. There is no time to think.

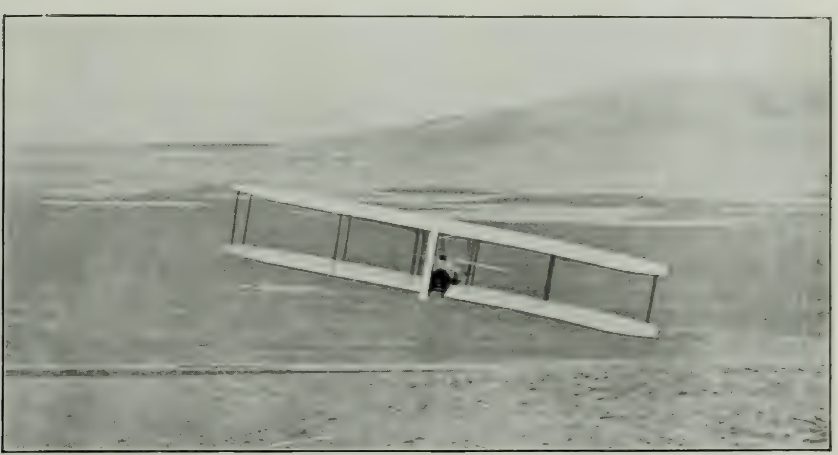
During a period of five weeks glides were made whenever the weather conditions were favorable. Many days were lost on account of rain. Still more were lost on account of light winds. Whenever the breeze fell below six miles an hour, very hard running was required to get the machine started, and the task of carrying it back up the hill was real labor. A relative speed of at least 18 miles an hour was required for gliding, while to obtain a speed of 12 miles by running required very severe exertion. Consequently unless the wind blew in our faces with a speed of at least six miles we did not usually attempt to practice; but when the wind rose to 20 miles an hour, gliding was real sport, for starting was easy and the labor of carrying the machine back up hill was performed by the wind. On the day when the wind rose to over 16 meters a second we made more than a hundred glides with much less physical exhaustion than resulted from twenty or thirty glides on days when the wind was light. No complete record was kept of all the



Starting a Flight.

glides made during the season. In the last six days of experiment we made more than 375, but these included our very best days. The total number for the season was probably between 700 and 1,000. The longest glide was 622½ feet, and the time 26 seconds.

The prime object in these experiments was to obtain practice in the management of a man-carrying machine, but an object of scarcely less importance was to obtain data for the study of the scientific problems involved in flight. Observations were almost constantly being made for the purpose of determining the amount and direction of the pressures upon the sustaining wings; the minimum speed required for support; the speed and angle of incidence at which the horizontal resistance became least; and the minimum angle of descent at which it was possible to glide. To determine any of these points with exactness was found to be very difficult indeed, but by careful observations under test conditions it was possible to obtain reasonably close approximations. It was found that a speed of about sixteen miles an hour would produce a pressure sufficient to support machine and operator, but the angle of incidence was too great for general gliding purposes. At eighteen miles the angle of incidence was about eight degrees, and the machine would glide on the Little Hill, descending at an angle of a little over seven degrees. Although the wings were inclined slightly above the horizon the machine continued to glide without loss of velocity. With a speed of 22 miles an hour, the angle of incidence required for support was four or five degrees, and the angle of descent a little less than seven degrees. At this speed the surfaces were inclined several degrees below the horizon. As the speed became greater the



Turning to the Right.

angle of incidence continued to grow less, but the angle of descent became greater again, thus showing that the point of minimum resistance had been passed. Scores of glides were made at angles of descent under six degrees, and in a few cases we reached five degrees. On the last day of experiment we made a few attempts at records. A line was drawn a short distance up the slope as a starting mark, and four trials were made. Twice the machine landed on the same spot. The distance was 156½ feet, and the angle of descent exactly five degrees. Time, 6½ seconds. From a point higher up the slope the best angle was 5 degrees and 25 minutes, for a glide of 225 feet. Time, 10¼ seconds. The wind was blowing about nine miles an hour. The glides were made directly to windward and straight down the slope. Taking seven degrees as a conservative estimate of the normal angle of descent, the horizontal resistance of the machine was 30 pounds, as computed by multiplying the total weight, 250 pounds, by the tangent of the angle of descent. This resistance remained nearly constant at speeds between 18 and 25 miles an hour. Above or below these limits there was a somewhat rapid increase. At 18 miles the power consumed was one and one-half horse-power; at 25 miles, two horse-power. At the slower speed, 166 pounds were sustained for each horse-power consumed; at the higher speed, 125 pounds per horse-power. Between 18 and 25 miles the horse-power increased almost in exact ratio to the increase in speed, but above or below these limits the power increased rapidly, and with a constantly accelerating ratio.

On two occasions we observed a phenomenon whose nature we were not able to determine with certainty. One day my brother noticed in several glides a peculiar tapping as if some part of the machine were loose and flapping. Careful examination failed to disclose anything about the machine which could possibly cause it. Some weeks later, while I was making a glide, the same peculiar tapping began again in the midst of a wind gust. It felt like little waves striking the bottom of a flat bottomed row-boat. While I was wondering what the cause could be, the machine suddenly, but without any noticeable change in its inclination to the horizon, dropped a distance of nearly ten feet, and in the twinkling of an eye was flat on the ground. I am certain that the gust went out with a downward trend which struck the surfaces on the upper side. The descent was at first more rapid than that due to gravity, for my body apparently rose off the machine till only my hands and feet touched it. Toward the end the descent was slower. It may be that the tapping was caused by the wind rapidly striking the surfaces alternately on the upper and the lower sides. It is a rule almost universal that gusts come on with a rising trend and die out with a descending trend, but on these particular occasions there must have been a most unusual turmoil during the continuance of the gust which would have exhibited a very interesting spectacle had it been visible to the eye. Irregularities of the wind are most noticeable when the wind is high, on account of the greater power then exhibited, but light winds show almost equal relative variations. An aviator must expect to encounter in every flight variations in velocity, in direction, and in upward or downward trend. And these variations not only give rise to those disturbances of the equilibrium which result from the travel of the center of pressure due to the changed angle of incidence, but also, by reason of the fact that the wind changes do not occur simultaneously or uniformly over the entire machine, give rise to a second series of disturbances of even more troublesome character. Thus a gust coming on very suddenly will strike the front of the machine and throw it up before the back part is acted upon at all. Or the right wing may encounter a wind of very different velocity and trend from the left wing and the machine will tend to turn over sidewise. The problem of overcoming these disturbances by automatic means has engaged the attention of many very ingenious minds, but to my brother and myself it has seemed preferable to depend entirely on intelligent control. In all of our machines the maintenance of the equilibrium has been dependent on the skill and constant vigilance of the aviators.

In addition to the work with the machine we also made many observations on the flight of soaring birds, which were very abundant in the vicinity of our camp. Bald eagles, ospreys, hawks and buzzards gave us daily exhibitions of their powers. The buzzards were the most numerous and were the most persistent soarers. They apparently never flapped except when it was absolutely necessary, while the eagles and hawks usually soared only when they were at leisure. Two methods of soaring were employed. When the weather was cold and damp and the wind strong, the buzzards would be seen soaring back and forth along the hills or at the edge of a clump of trees. They were evidently taking advantage of the current of air flowing upward over these obstructions. On such days they were often utterly unable to soar except in these special places. But on warm clear days when the wind was light they would be seen high in the air soaring in great circles. Usually however it seemed to be necessary to reach a height of several hundred feet by flapping before this style of soaring became possible. Frequently a great number of them would begin circling in one spot, rising together higher and higher till finally they would disperse, each gliding off in whatever direction it wished to go. At such times other buzzards only a short distance away found it necessary to flap frequently in order to maintain themselves. But when they reached a point beneath the circling flock they too began to rise on motionless wings. This seemed to indicate that rising columns of air do not exist everywhere, but that the birds must find them. They evidently watch each other and when one finds a rising current the others quickly make their way to it. One day when scarce a breath of wind was stirring on the ground, we noticed two bald eagles sailing in circling sweeps at a height of probably 500 feet. After a time our attention was attracted to the flashing of some object considerably lower down. Examination with a field glass proved it to be a feather which one of the birds had evidently cast. As it seemed apparent that it would come to earth only a short distance away some of our party started to get it. But in a little while it was noticed that the feather was no longer falling but on the contrary was rising rapidly. It finally went out of sight upward. It apparently was drawn into the same rising current in which the eagles were soaring, and was carried up like the birds.

The days when the wind blew horizontally gave us the most satisfactory observations, as then the birds were compelled to make use of the currents flowing up the sides of the hills and it was possible for us to measure the velocity and trend of the wind in which the soaring was performed. One day four buzzards began soaring on the northeast slope of the Big Hill at a height of only ten or twelve feet from the surface. We took a position to windward and about 1,200 feet distant. The clinometer showed that they were 4½ to 5½ degrees above our horizon. We could see them very distinctly with a field glass. When facing us the under side of their wings made a broad band on the sky, but when in circling they faced from us we could no longer see the under side of their wings. Though the wings then made little more than a line on the sky the glass showed clearly that it was not the under side that we saw. It was evident that the buzzards were soaring with their wings constantly inclined about five degrees above the horizon. They were attempting to gain sufficient altitude to enable them to glide to the ocean beach three-fourths of a mile distant, but after reaching a height of about 75 feet above the top of the hill they seemed to be unable to rise higher, though they tried a long time. At last they started to glide toward the ocean but were compelled to begin flapping almost immediately. We at once measured the slope and the wind. The former was 12½ degrees; the latter was six to eight meters per second. Since the wings were inclined 5 degrees above the horizon and the wind had a rising trend of fully 12 degrees, the angle of incidence was about 17 degrees. The wind did not average more than seven meters, 15 miles an hour. For the most part the birds faced the wind steadily, but in the lulls they were compelled to circle or glide back and forth in order to obtain speed sufficient to provide support. As the buzzard weighs about .8 pounds per square foot of wing area, the lifting power of the wind at 17 degrees angle of incidence was apparently as great as it would have been had it been blowing straight upward with equal velocity. The pressure was inclined 5 degrees in front of the normal, and the angle of descent was 12½ degrees.

On another day I stood on top of the West Hill directly behind a buzzard which was soaring on the steep southern slope. It was just on a level with my eye and not more than 75 feet distant. For some time it remained almost motionless. Although the wings were inclined about five degrees above the horizon, it was not driven backward by the wind. This bird is specially adapted to soaring at large angles of incidence in strongly rising currents. Its wings are deeply curved. Unless the upward trend amounts to at least eight degrees it seems to be unable to maintain itself. One day we watched a flock attempting to soar on the west slope of the Big Hill, which has a descent of nearly nine degrees. The birds would start near the top and glide down along the slope very much as we did with the machine, but we noticed that whenever they glided parallel with the slope their speed diminished, and when their speed was maintained the angle of descent was greater than that of the hill. In every case they found it necessary to flap before they had gone two hundred feet. They tried time and again but always with the same results. Finally they resorted to hard flapping till a height of about 150 feet above the top of the hill was reached, after which they were able to soar in circles without difficulty. On another day they finally succeeded in rising on almost the same slope, from which it was concluded that the buzzard's best angle of descent could not be far from eight degrees. There is no question in my mind that men can build wings having as little or less relative resistance than that of the best soaring birds. The bird's wings are undoubtedly very well designed indeed, but it is not any extraordinary efficiency that strikes with astonishment but rather the marvelous skill with which they are used. It is true that I have seen birds perform soaring feats of almost incredible nature in positions where it was not possible to measure the speed and trend of the wind, but whenever it was possible to determine by actual measurement the conditions under which the soaring was performed, it was easy to account for it on the basis of the results obtained with artificial wings. The soaring problem is apparently not so much one of better wings as of better operators.

DISCUSSION.

Mr. Chanute—Mr. Wright has advised you heretofore as to the advance made by others, but he has not advised you of the advance achieved by his recent experiments.

As regards the weight sustained per horse-power, which will perhaps strike you as being very small in comparison with the weights that are propelled either upon the land or water, you may remember that the machine experimented with by Mr. Maxim sustained only 28 pounds to the horse-power, and that the model experimented with in 1896 by Prof. Langley sustained only 31 pounds to the horse-power, while the machine experimented with by the Messrs. Wright sustains 165 pounds to the horse-power. It is true that a large deduction must be made from those figures when a motor is applied, but nevertheless they constitute a very great advance. Moreover, it is only when support is obtained at flat angles of gliding advance, that we may hope to apply power successfully and to fly through the air. The best experiments which I had been able to make in 1896 were to obtain angles of descent of 7½ to 11 degrees. Mr. Wright has been enabled to obtain angles of descent of 6 to 7 degrees, and in one case, as he has told you, a descent of only 5 degrees. This constitutes a very great progress and gives out a good hope of further advance hereafter.

I presume that some of you may desire to ask some questions of Mr. Wright, which I am sure he will be very glad to answer. The paper is now open for discussion.

Mr. Churchill—Is it true that, according to your results, to propel an airship by means of a motor or other means of propulsion, horizontally, the wings would have to be inclined about 17 degrees? That is to say, the angle would be 5 degrees plus 12½ degrees, as in the case of the buzzard?

Mr. Wright—No, that was simply an example of soaring. If it were desired to fly by mechanical means horizontally through the air, the best angle would be about 5 to 7 degrees; that is, the wings should be set probably in the neighborhood of 5 to 7 degrees above the horizon. In our machine the weight was about 250 to 260 pounds, on a little over 300 square feet area of the main surfaces—about .8 pound to the square foot—and we found that with a speed of 25 miles per hour the wings only had to be inclined about 3 or 3½ degrees.

Mr. Bainbridge—Do you think it is impossible for a bird to soar in a horizontal wind?

Mr. Wright—I do not think any bird soars in a horizontal wind. In order to soar it is necessary that the resultant of all the pressures produced by the relative wind be exactly vertical, but in a horizontal wind this pressure is always inclined at least 6 degrees backward from the vertical. It therefore has a horizontal component which would cause the bird to drift with the wind until the relative speed required for support was entirely lost. It is only in a rising trend of wind that the bird can obtain propelling forces to balance the drift and thus make the resultant of all the pressures vertical.

Mr. Warder—I would like to ask in regard to the covering and framework of this last machine.

Mr. Wright—In our frame the main body is made of spruce—the very best straight-grained spruce—which is almost as strong as the hard woods. The uprights and nearly all of the spars are made of spruce. The covering is of cloth.

Mr. Churchill—Have you made any experiments in propelling a machine with a motor?

Mr. Wright—We have not applied a motor to any of our machines. The driving force has been gravity.

Mr. Seddon—Have you followed the late experiments of Prof. Bell, and what do you think of them?

Mr. Wright—It is very bad policy to ask one flying-machine man about the experiments of another, because every flying-machine man thinks that his method is the only correct one. Prof. Bell is working on the plan of getting a machine of very great structural strength and one which he thinks can be maintained easily. I think his principal idea is simply the method of construction—to get something strong.

Mr. W. J. Wilson—I would like to ask Mr. Wright how he arrives at the area of the bird's wings.

Mr. Wright—The statement in regard to the area of the buzzard's wing was made on the authority of others. I have never measured one myself. As I understand it, the method is this: The bird, after being killed, is laid out flat, as nearly as possible in its position when flying and a line is drawn around the contour, and then the area is computed.

Mr. Warder—Does the bird throw the wing up or down without changing the axis of the body, or is it necessary to change the axis of the body at the same time he changes the plane of the wings?

Mr. Wright—Most birds incline the body to change the plane of the wings. Some years ago Prof. Marey made photographs of the flight of birds, employing a camera making fifty exposures a second. From these pictures it would appear that the bird's body rocks. The wings are moved diagonally forward on the down stroke, and backward on the up stroke. At the end of the down stroke the wings are in front of the center of gravity so that the bird's body turns up in front and remains so while the wings are being raised with a backward movement. But the wings being thus brought back of the center of gravity the axis of the body tilts downward again. By this backward and forward motion of the wings the bird rocks its whôle body and thus inclines the plane of its wings upward and downward with every stroke.

Mr. Churchill—Do you not utilize that principle, to a certain extent, in the front rudder? Has it that same effect?

Mr. Wright—We use the same principle that the bird uses in turning upward. That is, we get more pressure in front of the center of gravity. It may be that you misunderstood my statement in regard to my brother's experiments in low-gliding. I did not mean that he touched the ground; he kept 5 or 6 inches off the ground. Of course now and then he made a mistake and touched the ground.

Mr. Warder—In these glides that your brother made so close to the ground, do you not suppose there might have been a little more pressure than at 10 or 20 feet above the ground?

Mr. Wright—I do not think there is very much difference. We have found, by experimenting, that if you hold a surface stationary—almost touching the ground, it will have less lift than when it is up in the air. In gliding I do not think there will be very much difference.

A Visitor—I would like to ask first, whether you consider that the future flying machine will be the machine of the type you have been using, driven by screws, or whether it will be a machine having a flapping motion.

Another thought that occurred to me was that perhaps the machine wluod be less liable to capsize if the wings were on a dihedral angle of about 45 degrees on a horizontal line.

Mr. Wright—The dihedral angle is the system used by Mr. Maxim and by Prof. Langley. The Maxim machine was overturned by a side gust of only moderate force. The Langley machine was tested only in dead calms when there were no side gusts to contend with. In our first machine we set the wings at a dihedral angle, but when we found that every little side wind threatened to capsize it, we drew the tips down like the wings of a gull. The gulls fly in the stormiest weather, while buzzards which use the dihedral angle avoid high winds. We found the gull position much the best. The dihedral angle is the proper solution of the problem for flight in still air, but it makes matters worse instead of better when the wind blows. Unfortunately the wind usually blows, so we have found it best to abandon this method and employ other means of securing lateral equilibrium.

As none of our experiments have been with power machines, my judgment of the relative merits of screws and wings may be of little value. I suspect that in efficiency they are not far from equal, but that screws possess mechanical advantages.

Mr. F. E. Hermanns—I would like to ask whether you regard 160 pounds per horse-power as the maximum amount that can be obtained?

Mr. Wright—I think not. Theoretically the horse-power required to sustain a given weight could be reduced to almost nothing by greatly increasing the wing area and thus reducing the speed through the air. But this ignores some practical considerations. To reduce the speed one-half, it would be necessary to increase the wing area four times in order to sustain the original weight, and much more than four times in order to sustain the increased weight resulting from the additions to the machine. It is evident, therefore, that while there is a way by which the weight carried per horse-power can be increased, the road is difficult and becomes steeper at every step. The same result could be obtained by reducing the angle of descent, but here also a limit is being approached. Until the limit is reached in both respects it is possible to increase the weight carried per horse-power. I think 200 pounds is attainable, possibly a little more.

MISSISSIPPI RIVER BRIDGES.

1 Hennepin Avenue Suspension and later Steel Arch, Minneapolis.
2 Minneapolis Stone Arch, Railway.
3 Sixth Avenue, Minneapolis, Highway.
4 Great Northern Railway, Minneapolis.
5 Northern Pacific R. R., Minneapolis.
6 Washington Avenue, Minneapolis.
7 Franklin Avenue. Highway, Minneapolis.
8 C., M. & St. P. Ry., short line, Minneapolis.
9 Marshall Avenue, Highway, Minneapolis.
10 Fort Snelling (Highway).
11 C., St. P., M. & O. Ry. and C., M. & St. P. Ry., St. Paul.
12 Smith Avenue, Highway, St. Paul.
12 Wabasha Street, Highway, St. Paul.
14 Robert Street, Highway, St. Paul.
15 Chicago Great Western R. R., St. Paul.
16 South St. Paul Belt Ry. and Highway, St. Paul Park, Newport, Minn.
17 Hastings, C., M. & St. P. Ry.
18 Hastings, Highway.
19 Red Wing, Minn. (Highway).
20 Reed's Landing, C., M. & St. P. Ry., Pontoon.
21 Winona, C. & N.-W. Ry.
22 Winona, Highway.
23 Winona, Railway.
24 La Crosse, C., M. & St. P. Ry.
25 La Crosse, Highway.
26 Prairie du Chien, C., M. & St. P. Ry , Pontoon.
27 Eagle Point, Dubuque, Highway.
28 Dubuque, Railway.
29 Dubuque, Highway.
30 Sabula, C., M. & St. P. Ry.
31 Lyons and Fulton, Highway.
32 Clinton, Iowa, C. & N.-W. Ry.
33 Clinton. Iowa, Highway.
34 U. S. Rock Island Bridge, Highway and Railway.
35 Davenport and Rock Island R. R.
36 Muscatine, Iowa, Highway.
37 Keithsburg, Ill., Railway Bridge.
38 Burlington, C., B. & Q. R. R.
39 Ft. Madison, Railway and Highway.
40 Keokuk, Iowa, Railway and Highway.
41 Quincy and Quincy Bay, Ill., C., B. & Q. R. R.
42 Hannibal, Mo., Wabash R. R.
43 Louisiana, Mo., C. & A. R. R.
44 Alton, Ill., C., B. & Q. R. R.
45 St. Louis Merchants Bridge.
46 St. Louis Eads Bridge, Railway and Highway.
47 Thebes Bridge, Railway.
48 Memphis, Tenn., R. R. and Highway.

THE MISSISSIPPI RIVER BRIDGES.

Historical and Descriptive Sketch of the Bridges over the Mississippi River.

Mr. F. B. Maltby, U. S. Asst. Engr.*

The subject of "Bridging the Mississippi River between St. Paul and St. Louis" is exhaustively treated in a report with that title, made by G. K. Warren, Major of Engineers and Brevet-Major General, U. S. A., and printed in the annual report of the Chief of Engineers, U. S. A., for the year 1878. This report is a voluminous and complete one, covering the bridges in existence up to 1876 — 15 in number — and is generally considered the best authority on the subject covering the period up to that date. Since that time the number of bridges over the river below the Falls of St. Anthony has increased some three-fold, and the object in view in the preparation of this paper has been to bring the history of the subject down to date.

As Major Warren's report is now out of print, and not readily obtainable, and in order to make this description as complete as possible, the subject matter of his report is included in this paper in a somewhat condensed form.

1 MINNEAPOLIS; HENNEPIN AVENUE.

Highway.

The first bridge of importance completed over the Mississippi river was built at Minneapolis in 1855, though it is possible that the old Rock Island bridge was commenced at a prior date. It was a suspension bridge of about 620 feet span and was located in about the same position as that occupied at present by the steel arch bridge at the foot of Hennepin Avenue. This bridge was a very light structure, but stood remarkably well the increasing loads put on it for 20 years. The cables — 4 in number — contained about 2,000 strands of No. 10 soft iron wire. The cables were supported by wooden towers and the anchorage was formed by links running entirely through a ledge of limestone about 10 feet thick which overlies the soft sandstone.

The bridge was replaced with another suspension bridge built in 1876-77, which had a span of about 675 feet. It had 4 cables, each containing 3,648 strands of No. 9 iron wire, supported on masonry towers about 111 feet high.† This bridge has again been replaced, by a steel arch.

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* This paper was prepared in 1900, and some changes in some of the bridges have been made since then.

† *Engineering News*, 1878, page 85.

It is proposed to confine this paper to a description of the bridges below the falls, and this bridge is only mentioned on account of its historical importance.

It is thought that the first railroad bridge over the Mississippi river was the draw bridge at Rock Island built in 1853-56, and torn down in 1872, and described further on.

Hennepin Ave., Minneapolis. Highway. Transition of Suspension to Steel Arch.

Prior to 1866 it does not appear that the authority of Congress was deemed necessary before commencing the erection of a bridge over the river. This year was, however, a prolific one in bridge legislation by the national legislature. Seven bridges were authorized and built within a few years: namely at Winona, Dubuque, Burlington, Keokuk, Quincy, Hannibal and the St. Louis "Eads" bridge. In addition a bridge was authorized at Prairie du Chien in the same act, but was not built at that time.

The general provisions of the act were "That if built as high "bridges they should be 50 feet above extreme high water, with "spans not less than 250 feet in length, and one main or channel span "not less than 300 feet in length; if built as draw bridges they should "have two draw openings of 160 feet in the clear, and the next adjoining spans should not be less than 250 feet and should be 10 "feet above high water and 30 feet above low water." It provided "that the bridge at St. Louis should not be a suspension or draw "bridge, but should be of continuous or unbroken spans with the "bottom chord, at its greatest span, 50 feet above the city directrix; "that it should have at least one span 500 feet in the clear, or two "spans of 350 feet in the clear; that no span over the water at low "water stage should be less than 200 feet in the clear.

The River and Harbor act of the same year provided for "examining and reporting upon the subject of constructing railroad "bridges across the Mississippi between St. Paul and St. Louis upon "such plans of construction as will offer the least impediment to the "navigation of the river." The report of Major Warren referred to is the outcome of this provision.

In considering the bridges at different points it has seemed impracticable to take them up in chronological order without confusion, and they are therefore described in the order in which they are found in proceeding down the river beginning at the Falls of St. Anthony.

The information concerning the various structures has been obtained through a thorough search of the files of technical periodicals, by correspondence with those persons who are, or have been, connected with the bridges in an official capacity, and by a personal inspection of the structures.

It is impossible to acknowledge in each instance the source of information, and the writer desires to express here his appreciation of the kindness and courtesy of those who have so promptly and cheerfully furnished much of the data contained herein.

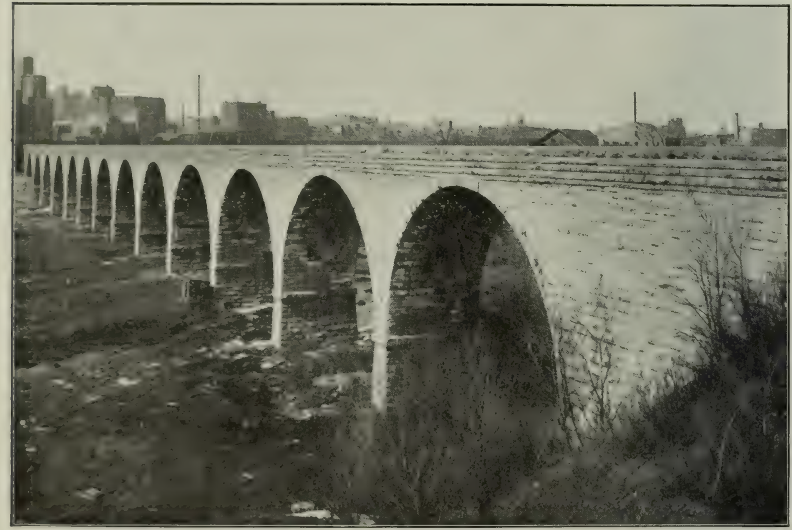
It has been the desire of the writer to state facts only and to make the descriptions strictly accurate, and he has, so far as possible, corroborated them, but undoubtedly some errors have crept in, and it is hoped that they may be corrected by such members as may be in possession of more definite and positive information than was obtainable by the writer.

2 MINNEAPOLIS; STONE ARCH.

Railway Viaduct—Built in 1882-83.

The first bridge below the falls is a magnificent stone arch viaduct, built and owned by the Minneapolis Union Railway. It is located immediately below the falls, the west end in fact passing above them. The river at this point is about 1,000 feet wide, with steep banks, rocky bottom and is not navigable at any stage. The bridge crosses the river diagonally and has a total length of 2,490 feet; the eastern 1,033 feet is on a straight line and the remainder is on a 6-degree curve to the right.

Commencing at the east abutment the structure consists of first nine stone arches with a span of 80 feet each. They are semicircular and have a key of 2 feet 8 inches; then four arches with a span of 100 feet each, segmental, with a rise of 39 feet 8 inches, and with a depth of key of 3 feet; then six arches with the same dimensions as the first mentioned, then one arch with 71.36 feet span, the east half being semicircular and the west half segmental with a rise of 15 feet, depth of key 2 feet 8 inches, then a 40-foot arch, segmental, with a rise of 5 feet 4 inches, and a key 2 feet 8 inches in depth, then an arch with a span of 43.86 feet, segmental, with a rise of 13 feet, and a key 2 feet 6 inches in depth, to the stone dam at the falls. Thence across this dam to the structure across the water power canal above the dam, forming a continuation of the viaduct. The latter structure consists of two skew iron girder spans aggregating 85 feet in length, two through pin connected iron spans each 130 feet in length, resting on tubular piers made of boiler iron filled with concrete, then a 40-foot iron girder reaching to the west abutment.



Stone Arch Railway Viaduct, Minneapolis.

The size of the piers commencing at the east end is as follows:

No. 1, the abutment.

Nos. 2, 3, 4, 5, 6, 7, 8 and 9, 7 x 26 feet under the coping.

No. 10, 14 x 26 feet under the coping.

Nos. 11, 12 and 13, 10 x 26 feet under the coping.

No. 14, 13 feet 4 $\frac{5}{16}$ inches on inside, and 14 feet 7⅞ inches on outside of curve by 26 feet under the coping.

Nos. 15, 16, 17, 18 and 19, 7 feet 1⅓-inch on inside, 9 feet 6 inches on outside of curve by 26 feet under the coping.

No. 20, 10 feet 8¼ inches on inside, 13 feet 1 $\frac{1}{10}$-inch on outside of curve by 26 feet under the coping.

No. 21, 8 feet 9 inches x 26 feet under the coping.

No. 22, 10 feet 2 inches x 26 feet under the coping.

No. 23, abutment in dam.

The piers are Minnesota granite up to the spring line, and all above that is magnesian limestone. The foundations below the dam are on soft sandstone which underlies the limestone at the falls. The deepest foundation is at Pier No. 13 and is 17 feet below low water. The bridge is a double track structure and is 28 feet wide. over the parapet walls; the grade line is 65 feet above low water,

The bridge was designed under the charge of Col. Chas. C. Smith, at that time Chief Engineer of the St. Paul, Minneapolis & Manitoba Ry. and its proprietary line the Minneapolis Union Ry. It was built by Darragh & Haviland, and contains 30,554 yards of masonry, and about 10,000 yards of stone filling. It cost approximately $650,000.

This magnificent structure is the only stone bridge on the river below the falls.

A photograph and profile of this structure are shown.*

3 MINNEAPOLIS; SIXTH AVENUE.

Highway—Built in 1872.

The second bridge below the falls is a highway bridge at the foot of Sixth Avenue in Minneapolis. The east end is only a few feet from the end of the stone viaduct just described. It is a deck structure and consists of six spans, the western three being about 200 feet long, center to center of piers, and the other three having a length of about 166 feet each. The eastern span is over ground entirely above high water, while on the west end the bank slopes very rapidly to the water's edge. Both ends of the bridge rest on solid rock and the abutments consist only of retaining walls to support the earth filling.

Sixth Avenue, Highway, Minneapolis, with Stone Arch Railway Beyond.

The bridge is supported on masonry piers throughout, which rest on a foundation of limestone debris which rests on the "St. Peter" sandstone, being a part of the crest of St. Anthony Falls in its recession. The piers are of limestone and have no cutwater or ice breaker on the upstream end and the outer stones have disintegrated to a considerable extent. The trusses are of single intersection and have vertical end posts. The panel length of the long spans is 12 feet 4 inches, and that of the short spans 13 feet 8 inches; the trusses are about 18 feet apart, center to center. The posts are channels with plate covers and they are provided with castings at the top and bottom through which the pins for chord and lateral connection pass. The pins at the foot of the end posts pass through a slotted hole in the bed casting to provide for expansion. It is evident that this pin does not move in the slot and that it serves as a rocking bearing for the end posts. In consequence the rods in the end panels of the bottom chords, which are mere idlers, have been buckled by being thrown into compression.

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* I am indebted to Mr. Jno. F. Stevens, Chief Engineer, Great Northern Ry., for the above information.

The floor beams are a pair of trussed I-beams, and one of each pair extends beyond the chord and forms a support for the sidewalks. The stringers are of wood. The roadway is of plank, 17 feet wide, with two sidewalks of 5½ feet each. The height of the roadway above the water surface is 67 feet. The bridge was built by the King Bridge Co., and cost $160,000.

4 MINNEAPOLIS; GREAT NORTHERN RY.

Built 1891.

This bridge is located a short distance below Tenth Avenue, Minneapolis, and was built by and belongs to the Minneapolis Western R. R., which is operated by the Great Northern Railway Co.

The river in this locality has steep rocky banks, about 80 to 90 feet above the ordinary low water surface. The banks are somewhat more abrupt than indicated on the profile, owing to the fact that the axis of the bridge is at an angle of 40 degrees with the river bank on the west side, while on the east side the bridge is very nearly tangent with the top of the bluff.

The structure is a deck bridge throughout and consists, commencing on the east side, of first 11 plate girder spans of 60 feet each, alternating with the same number of 30-foot tower spans, also plate girders, then two spans of 150 feet each, a tower span of 30 feet, then a span of 141.756 feet, and one of 158 feet to a tower span of 30 feet, then a 60-foot span, a 30-foot span, one of 60 feet, and then a 30-foot span to the west abutment — 32 spans altogether, and with a total length of 1,830 feet. The 30 and 60 foot spans are all plate girders, while the longer spans are single intersection trusses. The latter are placed 14 feet apart, center to center, while the short spans, except where adjacent to long piers, are 10 feet apart, center to center. The superstructure, with the exception of the 141 and 158 foot spans, the adjacent ends of which rest on a masonry pier extending to the bottom chord, rests on iron towers, which in turn rest on low piers extending only a short distance above high water. The axes of all the piers and towers are at right angles to the axis of the bridge, except the high masonry pier mentioned above, which is in the main channel of the river and whose axis is at an angle of 40 degrees with the axis of the bridge. This fact accounts for the peculiar appearance of the truss over this pier as shown in the profile. The masonry is of Kettle River sandstone, put in by McMullen & Morris of Minneapolis.

Great Northern Railway, Minneapolis.

The railway is about 82 feet above low water. The short spans at the west end of the bridge and about 600 feet of the east end of the bridge is on a 6-degree curve, while the intervening portion is on a tangent.*

5 MINNEAPOLIS; NORTHERN PACIFIC R. R.

Built 1884-85.

This bridge is located about one mile below the falls and a very short distance above Washington Avenue, Minneapolis. The low water channel of the river is near the east side and at the foot of an abrupt rocky bluff. The bank on the west side has a much more gentle slope.

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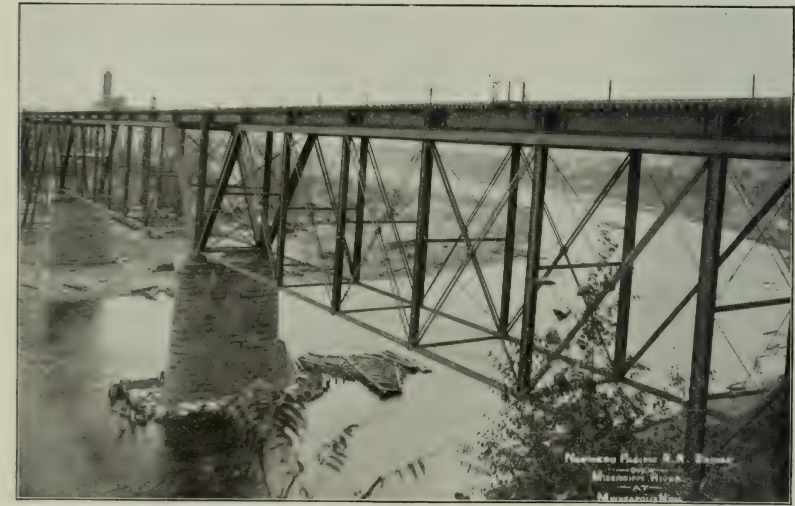
* Mr. C. J. A. Morris was engineer of the bridge, and the iron work was furnished and erected by the Shiffler Bridge Co., of Pittsburg.

I am indebted to Mr. Jno. F. Stevens for the above information

It was built by the St. Paul & Northern Pacific R. R. Co., a corporation which owned the line of railroad from St. Paul to Brainard. It was afterwards turned over to the Northern Pacific R. R., and is operated by that company.

It is a double track deck bridge, and beginning at the east end consists of two spans of 245 feet each, then a viaduct 750 feet in length composed of alternate 30 and 60 foot spans, the shorter spans being tower spans, the longer being inverted "A" trusses with two equal panels of 30 feet. The west end of the viaduct passes over a street and has a span, with very shallow truss, 64 feet long. A large portion of the viaduct is over ground somewhat above high water. The first two piers from the east abutment are in water. They are of limestone with granite coping and with granite facing to their upstream ends, which are triangular in shape to above high water. The masonry in these two piers extends to the bottom chords and the piers are about 60 feet high and they rest on the sand rock which forms the river bed. The piers under the steel towers extend just above ground, some of them go down to the rock and some of them rest in gravel and boulders. It was found that the surface of the bed rock under the earth on the west side of the river is lower than in the present river channel.



Northern Pacific Railway, Minneapolis.

The main spans are single intersection trusses and are divided into 8 panels. It is believed that at the the time the bridge was built the panel length of about 30 feet was greater than in any truss built in this country. The trusses are 42 feet deep, center to center, and are 24 feet apart. The floor beams are placed on top of the top chord, and the stringers are of uniform depth over the trusses and viaduct.

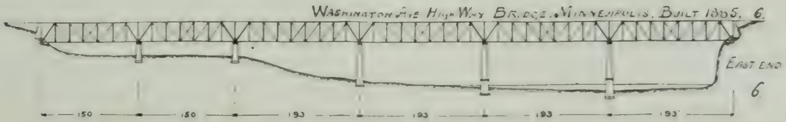
The roadway is about 101 feet above the water surface.

The bridge is entirely of steel and is one of the earliest of steel bridges.*

6 MINNEAPOLIS; WASHINGTON AVENUE.

A highway bridge built for the City of Minneapolis in 1885.

The river has the same characteristics as at the Northern Pacific bridge only a short distance above it.



The structure consists, commencing on the east side, of four spans of 193 feet each and two spans of 150 feet each, center to center of piers, a total length of 1,072 feet. The first two spans cross the river proper, the remaining spans being over the ground above high water.

The substructure is masonry throughout and the piers are built of limestone faced with granite on the upstream side. The foundation is rock. The piers are about 25 feet long on top and the top of the highest is 74 feet 4 inches above the bottom or about 55 feet above high water. They have triangular ends upstream with semicircular downstream ends extending above high water. Both ends of the bridge rest on solid rock with abutments for retaining walls only.

The superstructure originally consisted of Pratt Deck trusses 32 feet high and set 20 feet 5 inches apart, center to center. The roadway was 18 feet wide with two sidewalks each 6.5 feet wide.

In 1890, owing to the increased loads due to the growing traffic of the street railways, the bridge was strengthened by adding a center truss with top chord supporting the floor directly. The floor system was also strengthened by the addition of iron stringers.†

The roadway is paved with cedar blocks and has two street car tracks. The posts supporting the trolley wires are outside the trusses and run down to and are supported on the piers. The floor is about 97 feet above the water surface. The bridge was built by the Canton Bridge Co.

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* It was designed by Mr C. F. Loweth. The chief engineer for the railroad was J. W. Kendrick. The Edgemoor Bridge Co. was the contractor, with Onward Bates in charge of erection.

† See *Engineering Record*, July 18, 1896.

7 MINNEAPOLIS; FRANKLIN AVENUE.

Highway Bridge.

The river at this place, as well as at the next two bridges, is narrow with a swift current and with steep rocky bluffs on each shore.

The structure consists of a channel span of 300 feet and two spans of 172½ feet at each end reaching to the top of the bluff. The center or channel span is a half through span with the floor at about the center of the height of the truss. The end spans are deck spans, their shore ends being supported on masonry abutments near the top of the bluffs. The channel piers are both near the low water line, the length of the channel span very nearly representing the low water width of the river. They are of limestone and rest on solid rock and have triangular ends upstream to about the height of high water; they extend up to the bottom chord of the center span, the ends of the side spans resting in recesses in the sides of the piers. The roadway is about 18 feet wide and is paved with cedar blocks. There are two sidewalks 6 feet wide outside of the trusses, with the roadway 100 feet above the water.

The bridge was built in 1889 by the King Bridge Co., Cleveland, O.

8 MINNEAPOLIS; C., M. & ST. P. RY., (SHORT LINE).

Built 1879-80.

This structure is about one-half mile below Franklin Avenue and about one mile above the Marshall Avenue bridge, and as at these two bridges, the river is narrow, has a rocky bottom, swift current and steep bluffs on each side rising from the water's edge.

C. M. & St. P. Railway (Shortline), Minneapolis.

The structure consists of three main spans, the center one having a length of 324 feet and the end spans 272 feet each. At the west end there is a 40-foot and a 60-foot deck span, and on the east end there are three 60-foot deck spans reaching from the ends of the main spans to the abutments at the top of the bank.

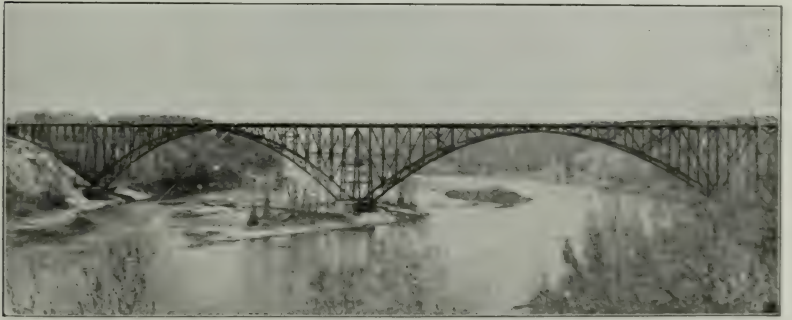
The piers under the main channel span are in the river and extend a short distance above high water, and are surmounted by single iron bents, which in turn support the superstructure. The west end of the west span rests on a masonry pier on the side of the bluff, while the east end of the east span is supported on iron cylindrical piers. The approach spans rest on iron trestle bents supported on smaller cylindrical piers. Considering the trusses in the main bridge, there are only two spans instead of three, as the trusses are continuous over the channel piers and project to the center of the channel opening, the chords being cut at this point. They are, therefore, true cantilevers.

The structure is a single track deck bridge, both chords of the main span are horizontal, and of the same depth throughout. The truss in detail is of the double intersection type with vertical posts. The end spans were erected on false work while the center span was projected without its use. The track is about 150 feet above low water. The bridge was designed and built by C. Shaler Smith. Plans have been made for a structure to replace the present one, having spans of somewhat different length and for a double track.

9 MINNEAPOLIS; MARSHALL AVENUE.

Highway—Built 1888-89.

This bridge joins Marshall Avenue, Minneapolis, and Lake Street, St. Paul. The river at this point is narrow and rapid, with rocky bluffs rising to a height of about 120 feet, and with a width at this elevation of 1,273 feet measured along the axis of the bridge. It was authorized by an act of the legislature of Minnesota which fixed the location and limited the cost to $150,000.



Marshall Avenue, Highway, Minneapolis.

The structure consists of three low piers supporting the ends of two 456-foot arch spans and three tall towers which carry the floor between the arches. There are two deck trusses 133 and 95 feet long respectively, connecting the arch spans with short girder and trestle approaches. The center pier is on a small island, and rests on gravel at a depth of about 4 feet below low water. A bed of concrete about 3 feet thick rests directly on the gravel. The side piers rest on rock. The masonry is Mankato limestone with granite skewbacks and bearing stones. The roadway is 20 feet wide with 6-foot cantilever sidewalks on each side. The panel length is 19 feet throughout the structure.

The bridge was built under Mr. J. S. Sewall, M. W. S. E., as engineer, for the joint board of commissioners of Hennepin and Ramsey counties, by the Wrought Iron Bridge Co., of Canton, O. It was built under the general specifications of Mr. Sewall and, excepting the floor system which has 7 x 16-inch wooden stringers, was entirely of iron—no steel being allowed in its construction.

The main arches have triangular trussing between the lower chord and arch and the horizontal top chord, and is practically a three-hinged arch, as the top chord has no connection with the adjacent structure. The floor is paved with cedar blocks.*

10 FORT SNELLING.

Highway—Built 1879-80.

The Sundry Civil appropriation bill passed by the national Congress in 1878 contained an item appropriating $65,000 for aiding the construction of a free wagon bridge at the military reservation of Fort Snelling, Minn. The bridge was built by commissioners appointed for this purpose by the legislature of Minnesota, and Mr. J. S. Sewall, M. W. S. E., was their engineer.

The river valley at this point has a width of about 800 feet, with steep rocky bluffs 80 to 90 feet in height, on each side. The low water channel is only about one-half this distance in width.

Beginning on the west side, the structure consists of a span reaching from the top of the bluff to the first pier, which is at the edge of the water; this span also crosses over a railroad track and is 135 feet long; then the main channel span of 270 feet; then a span of 181½ feet; then 5 spans of about 65 feet, each supported by four intermediate tower spans of about 18 feet, to an abutment at the top of the bluff. All are deck spans.

The three main spans are of somewhat peculiar design. The shore end of the first is supported at the top chord, the opposite end is supported on the pier at the bottom chord. The channel ends of each of the two side spans have a single projecting inclined post, forming a cantilever, and supporting a suspended span over the channel. The east end of the third span has an inclined end post, the inclination, however, covering only half the ordinary panel length. The trusses are single intersection, but with intermediate supports for the chords. Both the top and bottom chords of the side spans are of latticed channels, the bottom chord of the channel span is of eye bars. The floor beams rest on top of the chord and are of iron; the stringers are of wood. The roadway is about 18 feet wide, with a single sidewalk 5 feet in width.

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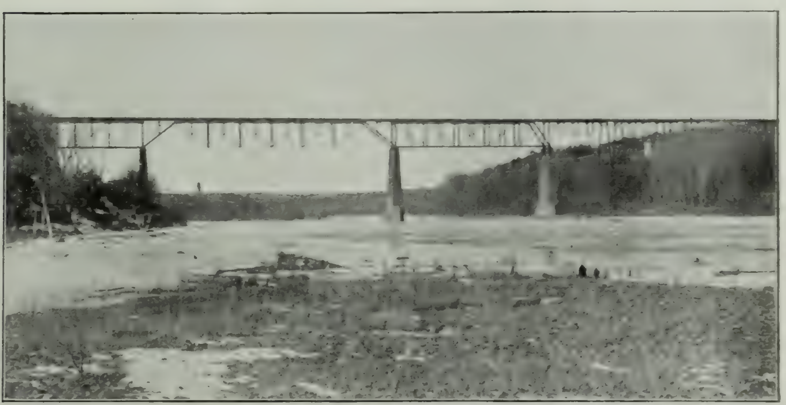
* See *Engineering Record*, Dec. 7, 1895, for details.



Fort Snelling—Highway.

The piers supporting the main spans extend to the bottom chord, the lower part is of limestone, and the upper portion of sandstone quarried in the immediate neighborhood. The first or west pier rests on rock about 20 feet below the water surface, the other two were sunk in caissons onto pile foundations, The piers have triangular ends upstream, faced with granite, and extending above high water. The towers are supported on low piers of masonry.

The superstructure was built by Mr. H. E. Horton, the contract having been awarded to him after a competition in which 32 bids, (all on competitive designs) were received. The original specifications required that the iron superstructure be so proportioned and constructed that with a load of 1,800 lbs. per lineal foot upon the whole or any part thereof, there should be no tensile strain upon any part of the structure exceeding 12,000 lbs. per square inch, and no compressive strain exceeding one-fourth the breaking load of the part as calculated by Gordon's formulæ.

Specifications also provided for a wind pressure of 50 lbs. per square foot, shearing strains on rivets and pins 8,000 lbs. per square inch, and iron in tension "to have an elastic limit exceeding 25,000 lbs. per square inch."

The bridge was completed in January, 1880, and was tested by the engineer having general supervision for the government, by loading it with ice to 1,800 lbs. per lineal foot, as provided in the specifications. The bridge successfully stood up under the load, but we are not informed of any methods used to ascertain whether the stresses in the members did or did not exceed the limits still further mentioned in the specifications.*

11 ST. PAUL; C., ST. P., M. & O. RY. AND C. M. & ST. P. RY.

The only authority for the construction of this bridge was granted by the territorial legislature of Minnesota in 1855. The bridge was built by the St. Paul & Sioux City Railroad Co., and was completed in 1869.

C., St. P., M. & O. R. R. and C., M. & St. P. Ry., St. Paul.

The left bank of the river at this point is a low bluff, while on the right bank there is a narrow bottom extending to the bluffs which are somewhat higher than on the left bank. The low water width was at this time about 1,300 feet with a high water width of 3,000 feet, the difference between high and low water was about 22 feet.

The original structure consisted of a trestle approach on the right bank, then a span of 150 feet, then a draw span 270 feet long over all, with clear openings of 114 feet, then six spans of 150 feet each. All the spans rested on masonry piers, which, with the exception of the draw pier, were 22 feet long and 7 feet wide on top, with a batter of ½ inch per foot. All except the one on the right bank had triangular ends upstream. The piers to the right of the draw, the draw, and the two piers to the left, rested on piles cut off below the water. The others rested on the bed of the river and were protected by rip-rap. The draw pier was 30 feet in diameter, and the guard pier was a rock filled crib.

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*Report of Chief of Engineers, U. S. A., 1880, p. 1869.

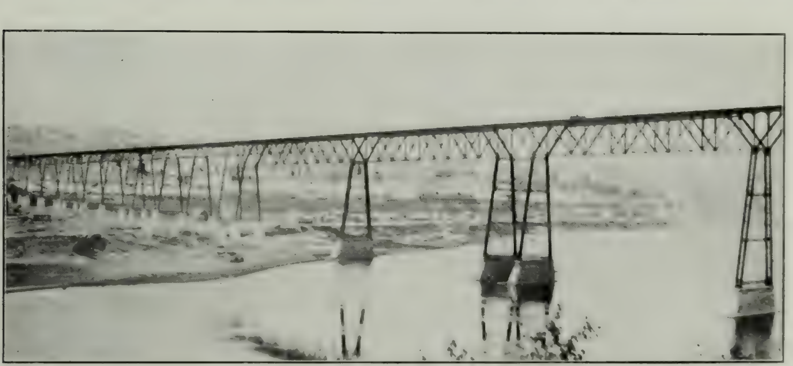
The superstructure was a Howe truss throughout. The short spans were 22½ feet high and the draw was 9 feet high at the ends and 26 feet at the center, and were built by the railroad company. The bridge was rebuilt with the same kind of trusses in 1876–77. The draw was rebuilt in iron in 1885 and the first span from the right bank in 1887. Both spans were built by the Lassig Bridge Co., and both are riveted lattice trusses. The remaining six spans were rebuilt in 1888 by the Keystone Bridge Co., and are Pratt trusses.

The old piers were used, and after 31 years of use are in remarkably good condition, showing very little deterioration.

12 ST. PAUL; SMITH AVENUE.

Built 1887-88.

This is a highway bridge built by the City of St. Paul, and situated about half-way between the C., St. P., M. & O. R. R. bridge and the Wabasha Street bridge. It extends from the bluffs on the St. Paul side to the bluffs on the right bank, and has a length between abutments of 2,770 feet. It is a deck structure throughout, with a roadway 24 feet wide and with two sidewalks each 8 feet in width, the total width between railings being 41.5 feet. The roadway is paved with cedar blocks and the structure has a clear height above low water of about 118 feet.



Smith Avenue—Highway—St. Paul, Minn.

The structure consists, commencing with the abutment on the south side, of first two 60-foot spans, a 170-foot span to a 50-foot tower span, then four 250-foot spans with a 50-foot tower span between the second and third, then a 50-foot tower span, three 90-foot spans to a 40-foot tower span, then nine 80-foot spans, between each three of which there is a 40-foot tower span, then two 90-foot spans to the abutment.

The substructure consists of the two abutments and 27 small piers on which rest the legs of the towers or bents. With the exception of those piers in the side of the bluffs, they extend a short distance above high water and rest on a pile foundation.

The superstructure is of wrought iron throughout, the trusses are 22 feet apart, center to center. The four 40-foot tower spans and the 60-foot spans are plate girders, the 80 and 90 foot spans are riveted lattice, while the three 50-foot tower spans, with the 170 and 250 foot spans, are pin connected. The adjacent ends of spans between towers rest on single trestle bents, which form rocker bearings, and which, with sliding joints at about every third span, provide for expansion in the short spans. The highest bent is 129 feet.*

13 ST. PAUL; WABASHA STREET.

One of the first bridges built over the river was a highway bridge at what is now the foot of Wabasha Street, St. Paul, completed in 1858. The only authority for its construction was granted by the territorial legislature of Minnesota in 1854. The act provided for a main span 300 feet long, between piers. This span was, however, made only 240 feet.

The river at the site of the bridge is divided into two channels by an island, the width between main banks at the time the bridge was built being about 1,200 feet. The original structure consisted of a trestle approach 375 feet long, on the right bank, to the first pier, then 7 spans 140 feet long, center to center, then a channel span 240 feet long, and lastly an 80-foot span, the outer end of which rested on the rock bluff. The first pier on the right bank rested on a grillage of timber below low water, and was 20 feet long and 5 feet wide on top, with a batter of ½ inch to the foot. The others were 7 feet wide on top. Those in the channel had triangular ends up to above high water, and rested on piles cut off as near the bottom as possible, and the masonry sunk onto them in caissons. The two piers on the island had no triangular end and no piles under them, the masonry resting on a timber grillage supported on a bed of rip-rap. The channel piers were 30 feet long and 7 feet wide on top, with a batter of ½ inch to the foot, and were 86 feet high above low water. They were built of limestone quarried in the neighborhood.

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* The superstructure was furnished by the Keystone Bridge Co., and erected by Mr. Horace E. Horton. Mr. A. W. Munster was engineer. Complete details of the superstructure can be found in the *Engineering Record* for February 16, 1889, et seq.

Wabasha Street—Highway—St. Paul.

The pier under the St. Paul end of the channel span was near the water's edge and at the foot of the steep rocky bluff, and it was supposed that it would rest on rock. It was found, however, that the rock sloped off so rapidly that it was necessary to drive piles under about one-third of the base of the pier. Timbers 24 inches square were used as grillage, one end of them resting on the piles and the other end on the rock.

The original superstructure was of a peculiar pattern, and was designed and built of wood by J. S. Sewall, M. W. S. E., and is described by him as follows:

"The trusses were Howe trusses with wooden suspenders in the "place of iron rods. The suspenders were notched onto iron angle "blocks which were set into daps in the chords like the angle blocks "of a Howe truss; chords were bolted to angle blocks. The 240-"foot span was a through span, the others deck spans. The chords "were level; the vertical members of the deck spans were carried "to the proper height above chord and capped by the floor beams. "At the ends of spans the posts stood on cast-iron shoes, there were "no corbels, but the truss stood on the end posts. At one end of "each 140-foot span these end members extended a few inches "below chord, at the other end seven feet and a few inches. The "panels were 10-foot. I think the 140-foot trusses were 16 feet "high.

"The long span had three trusses, panels 10-foot, double inter-"section, height probably 26 feet, lower chord sticks 7x20 inches "with 6x16-inch caps on lower chord over four-fifths of the span. "It stood on the end posts, the piers being but a few inches below "bottom of lower chords. The floor beams were 5 feet apart, "supported by lower chord, with blocking or short posts to get the "proper height. The span was further strengthened by arch "braces at each end extending from iron shoes 10 feet from ends "of chords to seats cut in the masonry of piers. The sketch shows "the connection of braces, suspensions and chords for the 140-foot "spans, the end posts being same as suspensions. The long span "detail is the same except the size of the chords. I have forgotten "how the counters were arranged in the 140-foot spans, but in the "long span they were cut in between the braces, with little bearing "plates. Thus each counter was cut into four lengths. They soon "became loose and useless. Very likely there never was a condi-"tion of loading that produced a strain on them. The other web "members were properly proportioned to the strains. The lateral "and diagonal systems were as usual and good. These trusses "never sagged. The 240-foot span lasted eleven years, when the "lower chord was found to be badly decayed. It was replaced by "a Howe truss of the usual type."

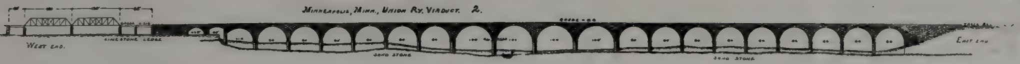
The roadway over the short spans was on a 5 per cent grade and over the channel span was about 3½ per cent.

The bridge was built by a company and toll charged. It was acquired by the City of St. Paul sometime prior to 1875, just when I have not learned, and since then has been a free bridge.

The bridge when completed was very little, if any, obstruction to navigation, and as at that time the only means of reaching St. Paul was by river, steamboat navigation was flourishing, and this fact probably explains the satisfactory provision for it. The first railroad communication to St. Paul was not opened till 9 years after the opening of the bridge.

The main span was rebuilt of wood, ordinary Howe truss, in 1869-70 and the others in 1872 on original plans. In 1879 the main channel span was replaced with iron. This span was of Whipple trusses of 16 panels, 30 feet in depth, and 20 feet 9 inches wide, center to center of trusses, giving a clear roadway of 17 feet and two sidewalks each 4.5 feet wide. The wooden spans, Nos. 3, 4, 5 and 6, counting from the St. Paul end, were rebuilt in 1883 with iron Pratt trusses 23.5 feet in depth and 17-foot centers, iron floor beams and wooden stringers. The first three spans were built

WESTERN SOCIETY OF ENGINEERS.
Vol. VIII. No. 4.—PLATE 1.
Maltby—Mississippi River Bridges.



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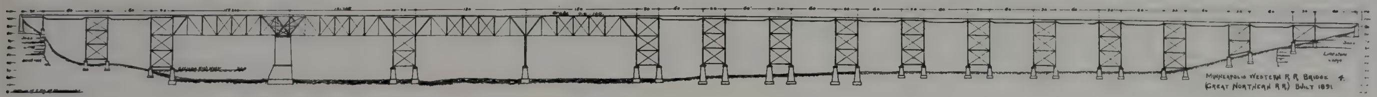
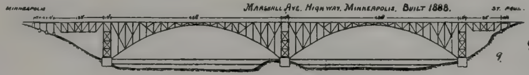


MINNEAPOLIS WESTERN R.R. BRIDGE 4.
(GREAT NORTHERN R.R.) BUILT 1891



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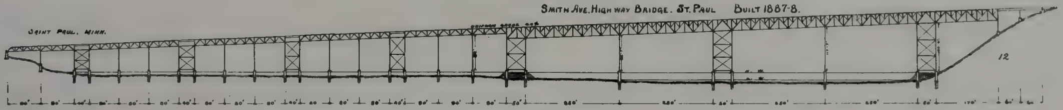

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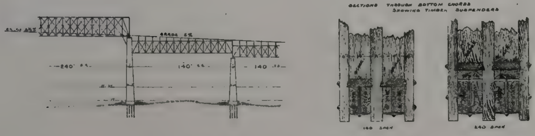

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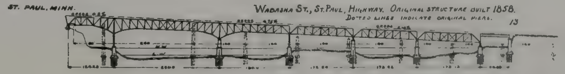
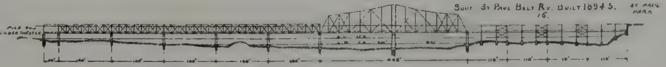
SKETCHES OF ORIGINAL WABASHA ST BRIDGE. ST. PAUL, MINN. 13a.



ST. PAUL, MINN.
WABASHA ST., ST. PAUL, HIGHWAY. ORIGINAL STRUCTURE BUILT 1858.
DOTTED LINES INDICATE ORIGINAL PIERS.
13

13



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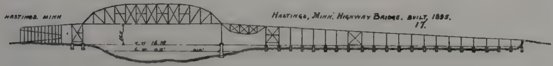

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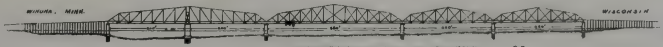

C.B.& N.R.R. BRIDGE WINONA, MINN. BUILT 1890-91 23

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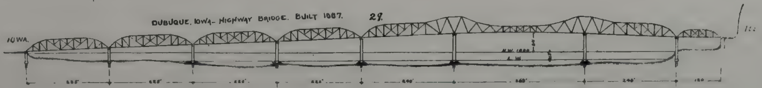

29

by the Missouri Valley Bridge Co. and the other by Horace E. Horton, the old piers being used. The remaining wooden spans were replaced in 1884-85 with Pratt trusses, piers 8 and 9 were used, but the last three spans were shortened to 110, 125 and 100 feet respectively, two new piers and an abutment were built and the pile approach filled up.

In 1889 the spans over the main channel were again replaced by a new structure. As it was desirable to have a deck bridge throughout and to very materially widen the roadway, and as the masonry of the old piers was not fit for rebuilding, an entirely new structure was designed. The new bridge, commencing at the bluff, consisted of a span 135 feet long, a channel span of 280 feet and a span of 187 feet. New piers were built resting on a pile foundation; the new spans are of the cantilever order. The end spans were erected on false work while the channel span was erected without it, the material being partly supported by the old bridge during erection. The roadway is 36 feet wide and is paved with brick. There are two sidewalks each 10 feet in width. The new spans were built by the Keystone Bridge Co. and were erected by Horace E. Horton and only 40 days elapsed after the receipt of the material until the bridge was again thrown open to the public. (*Engineering Record*, 1891-92, p. 58, for details of the new span.)

This year (1900) the remaining portion of the structure is being rebuilt to the full width of 56 feet. The arrangement of the spans, as well as that built in 1889, is shown on the profile, also the position of the piers in the original bridge. The new piers are all on pile foundations. The total length has been shortened to 1,200 feet by an embankment at the south end.*

To provide for the use of the bridge during the erection of the new one, the old spans were moved bodily to one side of their old position and supported on temporary pile piers.†

14 ST. PAUL; ROBERT STREET.

Highway—Built 1885-86.

This bridge is just below the Chicago, St. Paul & Kansas City Railway, and, in fact, it crosses over the latter bridge so that the end on the left bank is on the upstream side of it. The structure consists, commencing on the left side, of first five 18-foot plate girder spans, one 17.41-foot plate girder, one deck pin-connected span of 180 feet, then one through pin-connected inclined top chord channel span of 352 feet, then three deck pin-connected spans of 200 feet each, one deck pin-connected span of 150 feet, and two 55-foot plate girders to the abutment, the total length, center to center of abutments, being 1540.65 feet. The grade of the north end is 3.5 per cent and the south end 3.8 per cent, rising in each case toward the channel span which is level. Ths sub-structure consists of 14 pedestal masonry piers, 6 river piers and 2 abutments.

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* The new bridge is being built by the Wisconsin Bridge Co. on the design made by Mr. A. Munster, of St. Paul.

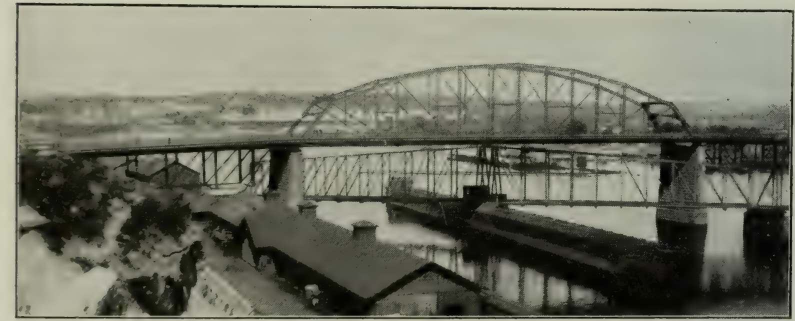
† This proceeding is described and illustrated by Mr. Munster in the *Jour. Engr. Societies*, Jan. 1900, and to him I am indebted for a large amount of the information concerning the history of this structure.

The chords of the trusses are 35 feet apart, center to center, and carry a roadway 32 feet wide, paved with cedar blocks, and two sidewalks, each 10 feet in width. The height of the roadway at the channel span is about 75 feet above low water. The channel span is single intersection, with intermediate supports for the chords. The end posts are about 30 inches square, and with the heavy portal bracing give the structure a very massive appearance.* It was built by the Morse Bridge Co., of Youngstown, Ohio.

15 ST. PAUL; CHICAGO GREAT WESTERN RY.

Built 1885.

This is a single track railroad bridge, located only a short distance below the Wabasha Street bridge. It crosses the river diagonally downstream from the right bank at an angle of about 55 degrees with the general direction of the river, and consists, commencing on the right bank, of 4 spans 222 feet long, center to center of piers, then a draw span 411 feet long on the center line, with clear openings of 175 feet, originally. These openings have been reduced by the construction of the piers of the Robert Street bridge, which passes over the draw span, to clear widths of 123 and 147 feet.



Robert Street Bridge and Chicago Great Western Draw Span,St . Paul.

The bridge is supported throughout on masonry piers of Mankato limestone, which rests on pile foundations cut off at the bottom of the river. The masonry in foundations was laid by the use of open cofferdams, except the main channel pier, which was sunk in open caissons. The draw pier is 30 feet in diameter, the others are about 7 feet wide on top by 30 feet long; the guard pier is a pile structure planked. The piers have triangular ends upstream, with a slope on the nose of about 1 to 1. The coping of the draw pier is just above extreme high water.

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* I am indebted to Mr. O. Claussen, City Engineer of St. Paul, for the above information.

The fixed spans are double intersection trusses with horizontal top chords. The draw is single intersection with the usual inclined top chord. The piers are parallel with the current and all the spans are thus on a skew. The fixed spans are 29 feet high, the draw 29 feet at the ends and 44 feet at the center; fixed spans are 17 feet wide, center to center, the track on a part of the draw is on a 6-degree curve and it is 25 feet wide, center to center, and its axis is set at an angle of about 2 degrees with the axis of the fixed span. Panel lengths in the draw are 18 feet 9 inches, while on the fixed spans they are 17 feet 6 inches. The draw is operated by steam.*

16 SOUTH ST. PAUL BELT RAILWAY BRIDGE.

This structure crosses the river near Newport, Minn., about 9 miles below the business center of St. Paul, and 3 miles below the Union Stock Yards. It forms a part of the South St. Paul Belt Ry., a line of road about 4 miles in length and connecting the Union Stock Yards on the west side of the river in South St. Paul with the main lines of the C., M. & St. P. Ry. and C., B. & Q. R. R. at Newport. In consideration of a bonus from the City of South St. Paul and Newport Township, provision was made for highway traffic.

Construction was begun in the summer of 1894, and the bridge was opened for traffic in April, 1895.

The structure has a double deck, the upper for railroad and the lower for highway traffic. To accommodate the latter the trusses were spaced so as to make a clear roadway 18 feet in width; no sidewalk is provided. The railroad grade on the east bank was so high as to necessitate placing the tracks on the upper deck. The highway is designed to accommodate an electric street railway, if ever desired, and has a clear head-room of about 13 feet.

Beginning at the east side the structure consists of a viaduct approach of 30 and 40 foot spans with an upper deck 440 feet long, and a highway floor 416 feet long; then a draw span 442 feet in length, center to center of piers; then 5 spans each of 140 feet in length, center to center of piers; then a 50-foot girder span; then 1,039 feet of pile and trestle approach.

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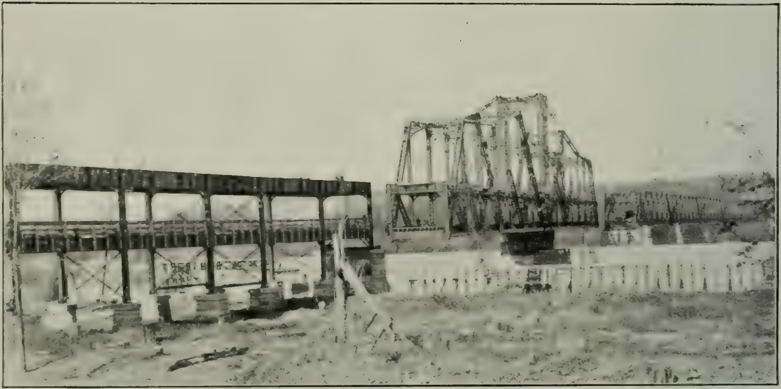
*The bridge was designed by C. Shaler Smith, the draw was built by the Passaic Rolling Mills and the fixed spans by the Edgemoor Bridge Co., with Mr. Onward Bates in charge of erection. G. W. Sherwood & Co., of St. Paul, built the substructure.

The highway floor is deflected from the axis of the bridge under the 50-foot girder span and by a short pile trestle is landed on earth embankment. The substructure throughout is of masonry piers; those in and adjoining the river have pile foundations. Generally the piles were sawed off at or below the river bottom and timber grillage used, of such thickness as each individual case would permit; the pier near the west side has no grillage, concrete over and about the piles being substituted. The masonry is built of magnesian limestone from Mankato, Minn. The protection or fender piers for the draw span are of pile and timber with a rock filled timber crib at the upstream end. The east end of the draw span is at the river bank, and from this pier, upstream, there is a pile and timber sheer-boom located along the water's edge and 800 feet in length, designed to facilitate the passage of log rafts through the opening.



South St. Paul Belt Railway and Highway.

The superstructure is of steel. The viaduct approach has at each third span a braced tower with a 30-foot span, the two intermediate spans being 40 feet and supported on rocking bents. All posts are vertical. Floor beams of the upper deck are rigidly connected to the posts and in addition have heavy brackets underneath, so as to take care of the lateral forces; below the lower deck are diagonal braces as in the usual construction.

The draw span is of the usual type, of two independent spans supported from a central tower, the top chords being curved. The trusses are 44 feet deep at ends and at the tower, 72 feet—the excessive end depth being necessary to give the required head-room of 22 feet above the railroad track. The span is 440 feet in length over all, with a central panel of 18 feet 7⅜ inches and 7 panels of 30 feet ¼ inch in each arm. The span has a rim-bearing turntable. Between the trusses and the drum are four large girders, placed transversely to the axis of the bridge, and connected together in pairs by twin girders under each central tower post; these four girders are so spaced as to distribute the load evenly at 8 equidistant points on the drum.

The turntable has 56 cast steel wheels, 18¼-inch diameter and 10½-inch face; the track is of cast iron, securely bolted to the masonry, and the upper tread is of forged steel, bolted to the lower flange of drum. The rack is of cast iron, secured with turned bolts to the lower track, with all bearing or contact surfaces between the two machines finished. The ends of span are supported on large double cast steel rollers, moving transversely to the axis of the bridge, and the track rails are raised and lowered by the same mechanism. The draw span was at first provided with a 50 H. P. gasoline engine, but this power proved unsatisfactory and last year was replaced with steam.

The five 140-foot spans are of the usual Pratt type of truss, divided in 7 equal panels. The upper floor beams are riveted into the truss posts below the top chords, and the lower floor beams above the bottom chords with bottom flange flush with bottom of truss posts, the same as in the draw span. Each panel of wind pressure at upper deck is supposed to go through the truss posts directly to the bottom lateral system, and thence to piers, the posts being proportioned on this basis, but in addition there is a supplemental but light lateral system along the upper deck.*

17 HASTINGS, MINNESOTA.

C. M. & St. P. Ry.—Built 1871.

The only authority for the construction of this bridge was granted by the Minnesota legislature in 1867.

The river in this vicinity crosses the valley from the left bank and strikes the low bluffs on the right bank, and there makes a sharp bend of nearly a right angle, only a short distance above the bridge; a location similar to that of the Hannibal bridge. The low water channel was about 400 feet wide, with a high water width extending from bluff to bluff of about 4,000 feet. The depth of water was from 18 to 22 feet, the current gentle and with a rise from low to high water of about 22 feet. The bridge was completed in 1871 by the Hastings & Dakota Railroad Co., afterwards acquired by the C. M. & St. P. Ry.

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* The Pittsburgh Bridge Co., Pittsburgh, Pa., was the contractor for the entire structure and sub-let the substructure and protection piers to Mr. Chas. Stone of St. Paul. Mr. W. W. Curtis, M. W. S. E., as the representative of the Pittsburgh Bridge Co., secured the contract and generally had charge of its construction for the contractors. The structure was designed and built under the supervision of Mr. Chas. F. Loweth, M. W. S. E., of St. Paul, Minn., to whom I am indebted for the above information.

The structure originally consisted, beginning on the right bank, of 235 feet of trestle approach; then a draw span 300 feet long over all with clear openings of 120 feet and 135 feet; then two spans of about 150 feet each and one of 106 feet; then about 2,286 feet of trestle to a bridge of two spans of 105 feet each; then 700 feet of trestle to the embankment. The main bridge was on a straight line.

The piers were built of limestone quarried in the vicinity and rest on piles, with the exception of the first one, which is on rock about 6 feet above low water and about 15 feet back from the shore line. The draw pier was 26¾ feet in diameter on top with a batter of ½ inch per foot. The piers at the ends of the draw span were 7 feet wide on top, the others 6 feet. Piers Nos. 3 and 4 were 30 feet long on top with triangular starlings extending about 18½ feet above low water, with a slope on the nose of 1 to 1. Piers 5 and 6 were of the same dimensions but had no starlings. The piers under the short spans near the bluffs were 5½ by 25½ feet on top with semi-circular ends. The guard piers were rock-filled cribs resting on the bottom of the river.

SUPERSTRUCTURE.—The draw and two adjoining spans (150 feet) were of the "Post" pattern, built by the American Bridge & Iron Co. The three 105-foot spans were a combination of wood and iron, built by the railroad company, and of the same form of truss. The draw was operated by hand. The lowest part of the structure was not over 6½ feet above high water (Warren). The 105-foot span over the river was rebuilt in 1880, and the draw and two remaining spans in 1891; all are of iron throughout and, as is the custom of this company, were built by the railway company itself. The old piers were used, their tops only being changed to meet the requirements of the new spans. The approach on the south or west side has been partly filled, while most of the trestle on the east side has been maintained, and was rebuilt in 1890. The spans and trestle near the north bluffs have been filled.

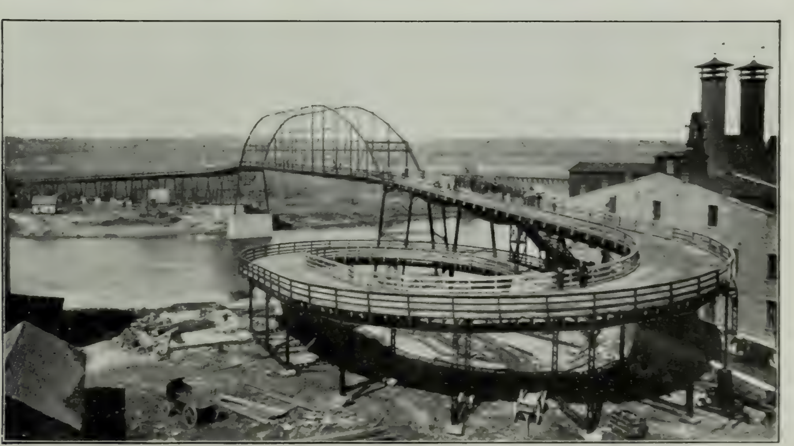
The new spans are all single intersection and have horizontal top chords. The short span has all the stringers riveted to the web of the floor beams and the bottom chord is of the ordinary eye bars; the longer fixed spans have stiff continuous bottom chords made of plates and angles and the floor beams are below the stringers and suspended from the chord. The new "draw" is operated by steam.

18

HASTINGS, MINN.

Highway—Built 1895.

Authorized by act of Congress in 1894. This bridge is located only about 1,000 feet downstream from the railroad bridge just described, and is a high bridge, the bottom chord of the channel span being about 55 feet above high water. Owing to the fact that the river is comparatively narrow and all confined to one channel, and that the banks are low, especially those on the north side, the greater part of the length of the structure is contained in the approaches, which are of steel trestle bents and plate girders with wooden joists and plank floor. Beginning with the trestle approach on the north or left bank, the structure consists of a deck span of about 135 feet; then the main channel span of about 375 feet to a tower span on the south bank; then two deck plate girder spans to the trestle approach. The south end of the main channel span is supported by two legs of the tower, which in turn rest on low piers extending above high water, and they in turn rest on the exposed solid rock and a few feet back of the low water line. The north end of the span and the adjacent end of the deck span rest on a single bent resting on a masonry pier extending above high water and which is in the water some 25 or 30 feet from the low water line. The trestle approach rests on low stone piers only a foot or two above the surface of the ground.



Hastings—Highway.

The main span is a through truss of single intersection with curved top chords, the five central panels only being horizontal. The trusses are spaced 24 feet apart, center to center, and are —— feet high. The roadway is 19 feet and one sidewalk 5 feet in width, both being inside the trusses. Owing to the height of the truss, the posts, which appear very light, are braced by longitudinal struts between alternate posts and at about the center of their height; they are also braced by lateral struts placed at about one-third and two-thirds of their vertical height. This bracing is in addition to the ordinary top lateral bracing. The deck span is divided into 5 panels and the bottom chord is curved, the center panel only being horizontal. The approach on the north end at a distance of about 75 feet from the end of the deck span makes a turn of about 45 degrees upstream. The south approach is peculiar in the fact that it is almost circular in plan and makes a complete turn of 360 degrees, the end where it reaches the street level being underneath and having a direction and position on the axis of the bridge prolonged. The length of the girders in the north approach is about 33 feet, while in the south approach, owing to the arrangement of bents, they vary in length, but are generally somewhat shorter. This is a free bridge belonging to the city.*

19

RED WING, MINNESOTA.

Highway.

Built by the City of Red Wing, Minn. Begun in the summer of 1894 and opened for traffic May 1st, 1895

It is a highway bridge and the city charges toll for passage over it. It was built for the purpose of increasing the city's trade with the adjoining country in Wisconsin, and supplanted a ferry.

The Minnesota end of the structure begins near the foot of the large bluff known as Barn Bluff and opposite the end of Bluff street in the city of Red Wing. The line of the bridge crosses the river squarely and immediately over the east or Wisconsin bank of the river the bridge turns up stream at an angle of 77 degrees 46 minutes by a short curve.

The main structure and its approaches are all substantially and permanently built. The general dimensions are as follows: Beginning at the intersection of Bluff and Main streets, there is an earth approach about 400 feet in length; then two 94-foot deck spans, the second one crossing over the tracks of the C., M. & St. P. Ry.; then a 430-foot channel span; then a 220-foot deck span; the shore end of which projects as a cantilever an additional distance of 37 feet; then a steel viaduct 839 feet in length then an earth embankment about 400 feet in length. On the earth embankments there is one 6-foot sidewalk and a 24-foot roadway, and over the spans and trestle there is one 6-foot sidewalk and a roadway 17 feet wide in the clear. The main channel span, which is the only through span, has trusses spaced far enough apart so as to be outside both roadway and sidewalk. Character of trusses in the several spans is shown on the photograph.

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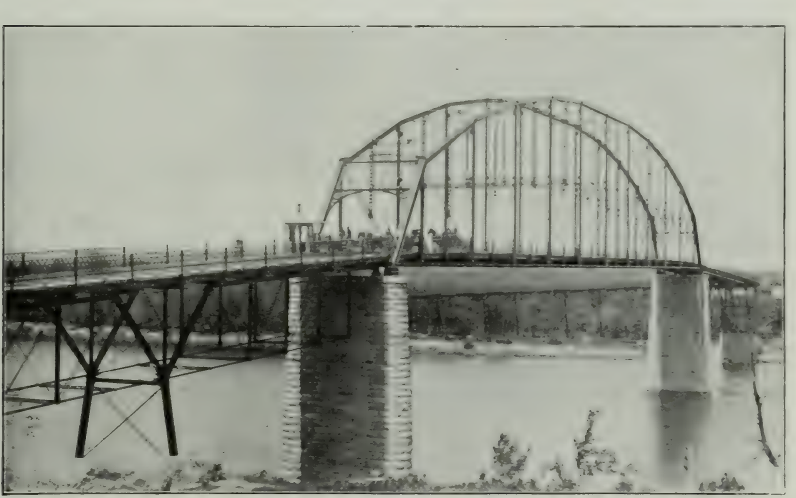
* The bridge was built by the Wisconsin Bridge & Iron Co., and John Geist was the engineer.

The higher portion of the Wisconsin approach trestle is made as is outlined in the sketch herewith. The two 94-foot spans on the city side are suported by a rocking bent between them.



Red Wing, Minn., Highway.

SUBSTRUCTURE.—The substructure is of substantial masonry work throughout: the abutments and piers for the two 94-foot spans are founded upon natural bed-rock. The two piers for the channel span are each of stone masonry and are 69 feet in height above low water mark of the river. The form of these piers is shown on the photograph herewith. The pier at the west side of the channel is near the edge of the river, while that at the east end of the span is well out into the river. The piers have pile foundations surmounted with timber grillage which extends to one foot below low water level. The easterly one of these large piers was in water 16 feet deep. The piles were cut off near the surface of the bottom of the river, and the timber grillage consists of 14 courses of 12-inch timbers. The top and bottom courses were laid solid, but the intermediate courses were approximately three-quarters solid. The piles were driven to a firm foundation and were from 40 to 60 feet in length below the level at which they were cut off. The foundation for the west one of these high piers was similar but in shallower water. The grillage was about 4 feet in thickness and much shorter piles were required.

The pier at the Wisconsin shore is upon a pile foundation; concrete being placed over and about the piles nearly to the ground surface.

The small piers for trestle approach have concrete footings, and above that are of large size stone masonry. The stone used throughout the work, except for starlings of river piers, is a hard magnesian limestone, quarried two and one-half miles from the bridge site, and is a hard, durable stone quite suitable for the purpose. The starlings of river piers from low to high water level are of granite from St. Cloud, Minn.

The superstructure was proportioned for live loads as follows:—

For floor system and secondary members throughout, including the viaduct approach, 100 lbs. per square foot, over both roadway and sidewalk.

The trusses of 94-foot spans, 1,680 lbs. per lineal foot.

For 220-foot span, 1,430 lbs. per lineal foot.

For 430-foot span, 1,200 lbs. per lineal foot.

All of the metal work is of steel excepting small rods, which were of iron. Flooring was three inches thick for the roadway, two inches for the sidewalks, and of white pine. Since construction, the roadway floor has been renewed with oak. The joists were of white pine, 15 lines of joists being used 4x14 inches for the channel span and for portion of the trestle, and 4x12 inches elsewhere.*

20 REED'S LANDING.

Pontoon Railway Bridge—Built 1882.

This bridge is located about one and one-half miles below the lower end of Lake Pepin, and a short distance below the mouth of the Chippewa River. It was built and is operated by the C. M. & St. P. Ry. Co. The river has a low water width of about 2,400 feet.

The bridge consists of an ordinary pile trestle with a pontoon draw about 400 feet in length, which gives a clear opening of about 350 feet. There were three openings in the trestle bridge which were spanned by Howe trusses 40, 70 and 90 feet in length.

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*The small piers for Wisconsin approach trestle were built by the city by day labor. All other substructures were built under contract by Mr. D. D. Smith of Minneapolis. The superstructure was built by the Toledo Bridge Company, Toledo, Ohio. The work was designed and construction supervised by Mr. Charles F. Loweth, M. W. S. E., of St. Paul, assisted in the field work by Mr. L. P. Wolff, city engineer.

I am indebted to Mr. Loweth for the above information.

A large amount of the trestle has been filled with rock to a little above low water. A description and discussion of the Prairie du Chien bridge, which is of the same type, will answer for this and will not be repeated here.

The bridge was rebuilt in 1891, and only two Howe trusses were built, one of 114 and one of 50-foot span.

21

WINONA.

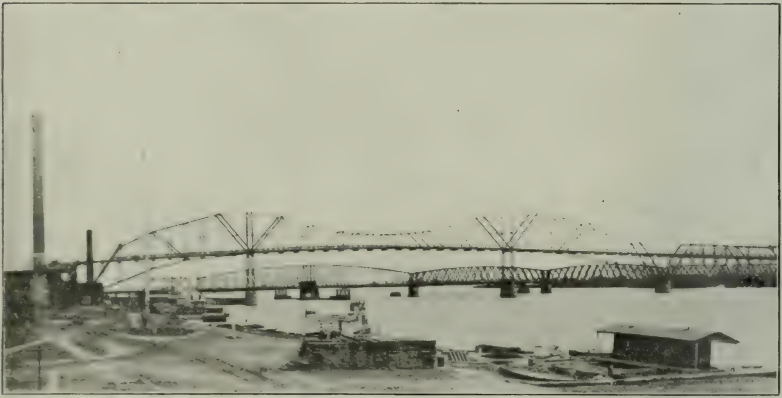
C. & N. W. Ry.

Built under act of congress in 1886, and opened to traffic in 1871. The town of Winona was situated on an isolated gravel terrace only a few feet above high water, and, originally, during high stages, there was water behind the town. Opposite the town there was an island with a channel about 700 feet wide on the opposite side; the main channel, about 10,000 feet in width, was next to the town. The whole bottom between bluffs in this vicinity is quite low and subject to overflow to several feet in depth. The distance between bluffs is about 3 miles; the range between high and low water is about 17 feet; the low water slope is 0.7 feet per mile, with a current of about 3 miles per hour.

The original structure consisted, commencing on the Winona side, of about 2,100 feet of trestling on a 1 per cent grade, and crossing two streets on 40-foot spans. The first span was 80 feet long; then a draw of 360 feet with clear openings of 160 feet each; then two spans of 250 feet each, to the island; then about 1,000 feet of trestle across the island; then four spans of 160 feet each; then about 400 feet of trestle to an embankment 487 feet long; then 360 feet of trestle to an embankment. There was also two spans of 132½ feet and 420 feet of trestle over a slough about one-half mile back from the river, making the original high water opening about 3,988 feet in width.

Substructure.—The piers under the four spans over the main river, except the one under the east end of the fourth span, are masonry resting on piles cut off at low water. The first pier came inside the water line. Nos. 2 and 4 were 8x30 feet on top, with a batter of ½ inch to the foot. They had triangular ends up-stream beginning about 8 feet below the top, with a slope on the nose of about 4 inches per foot. Pier No. 5 was 7 feet wide, but otherwise of the same dimensions. The draw pier was 33 feet in diameter on top; the guard piers were timber cribs with a row of piles running from them to each side of the draw pier. Pier No. 6 under the east end of the fourth span was of timber 11x37 feet and resting on a rock filled crib. The piers under the 160-foot spans were of piles with the lower part surrounded by a rock-filled crib.

SUPERSTRUCTURE.—Spans 1, 3 and 4 were Howe trusses, as were also the 160-foot spans. The draw was of iron of the Post pattern and was turned by steam. In 1876 the trestle across the island was replaced by 7 spans of Howe truss 142½ feet long, resting on three bent pile piers. This change was found necessary on account of the scour around the old trestle occasioned by the lodgement of driftwood against it. The trestle beyond the 160-foot spans over the east channel was replaced about 1875 by nine 45-foot queen post trusses resting on pile piers, and about the same time the 360-foot of trestle over the slough was replaced by two Howe trusses of 142½ feet and one 45-foot span, all resting on pile piers. (Warren.)



Highway and Railway Bridges, Winona, Minn.

Mr. Edw. C. Carter, Chief Engineer of the C. & N. W. Ry. writes that there were no queen post trusses in this structure. The Howe truss spans were replaced in 1886 by riveted lattices built by the Lassig Bridge & Iron Co. of Chicago. The draw span was replaced in the winter of 1898-99 by a pin connected span built by the Detroit Bridge & Iron Works. The original trestling outside the spans above mentioned has all been filled.

22 WINONA.

Highway Bridge.

This bridge was authorized by act of congress in 1890, and constructed in 1894. It is located only a very short distance below the C. & N. W. Ry. bridge. Owing to the location and the condition of traffic requirements at the Winona end, the approach could not be built in line with the channel spans. The approach starts at the intersection of Second and Main streets, with an embankment running to the alley between Front and Second streets on a grade of 4.22 per cent, then on a viaduct approach to Front street and across the tracks of the C. & N. W. Ry. Here the viaduct makes a right-angle turn with a radius of 50 feet and extends up Front street parallel with the river for about 300 feet, where with another right-angle turn with the same radius it enters the main structure. The latter consists of first a span of 200 feet; then the channel span of 360 feet; then a span of 250 feet; these three spans forming cantilevers over the intermediate piers; then comes a span of 250 feet to the timber trestle approach of the Wisconsin side.

The main structure rests on masonry piers which extend about 5 feet above high water and rest on pile and grillage foundations; piers 7x39 feet under coping. On piers 2 and 3, which support the channel span, iron towers were erected to give the spans the necessary height. At piers 1 and 4 the spans, which are of peculiar shape, rest directly on the piers. The bottom chord of the fourth truss is only about 5 feet above high water, and the roadway crosses it in a half-deck manner between the trusses and on a grade of about 4.5 per cent. The grade of the roadway on the first and third spans is also on a grade of 4.5 per cent, while on the channel span it is level and is 55 feet above high water. Spans 1, 3 and 4 were erected by mean of false work, while the main channel was projected from each end and was self-supporting. The trusses are pin connected with solid riveted floor connections. The roadway is 18 feet wide with a sidewalk 5 feet wide on one side only. The viaduct approach on the Winona side is of pin connected deck trusses set 40 to 60 feet apart, each end being supported by two braced iron posts forming a bent. The top chord was extended one panel length and braced to the bottom chords, thus forming a cantilever. The space between their extremities was bridged by the regular floor stringers.*

23 WINONA.

C. B. & N. R. R.—Built 1890.

This bridge was authorized by an act of congress in 1888, and is located near the east end of the city; and consists, beginning on the Minnesota side, of first, a draw span 440 feet long between end pins with clear openings of 200 feet; then one 360-foot span and two spans of 240 feet each. On the Minnesota side there was a trestle approach of 300 feet, and on the opposite side one of 1,200 feet.

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*The bridge was built for the city of Winona by the Chicago Bridge and Iron Company from designs by Horace E. Horton, president and engineer. Mr. George T. Baker, Davenport, Ia., was consulting engineer. See Engineering Record, August 25, 1894, for further particulars.

The first pier was a rectangular one 6x26 feet under the coping, with a batter of ½ inch per foot; the draw pier was 30 feet in diameter with no batter; the other piers are 8x22 feet under the coping, with a batter of ½ inch. The up-stream end is triangular in plan with a slope of 1 to 2 on the nose. All rest on timber grillage at least 2 feet under low water, and from 2 to 6 feet thick; this is in turn supported on piles which were driven with a steam hammer. The masonry is of limestone quarried in the vicinity.

The 240-foot spans are 17 feet wide; the 360-foot span and the draw are 20 feet wide. The panel length throughout is 30 feet, except over the center of the draw. The superstructure is generally of steel. The draw is 25 feet high at the ends and 50 feet high at the center.*

24 LA CROSSE.

C. M. & St. P. Ry.

The river in this vicinity flows at the foot of a sand terrace from 10 to 40 feet above high water, on the left bank of which is situated the city of La Crosse, Wis. There is a similar terrace on the opposite side of the river and about 2 to 2½ miles away, the intervening bottoms being overflowed in high water to a considerable extent. The bluffs are some distance farther back. The river has a flat slope and a gentle current, and the channel is divided by numerous islands. The range between high and low water is about 16 feet.

A bridge at this place was authorized by Congress in 1868, but was not built. The act of 1872 authorized the Milwaukee & St. Paul Ry. Co. to build a bridge at any point they might select between the counties of LaCrosse, Wis., and Houston, Minn. Considerable discussion arose over the location of the bridge, but in 1875 the railroad company was allowed to proceed with the construction at their own site across the lower end of Minnesota island and about two miles above La Crosse. It was opened to traffic in December, 1876.

The original structure consisted of a draw span 310 feet long over the Black River, then about 4,000 feet of trestle over French Slough to the east channel, which was crossed by 5 spans of 148 feet each; then 650 feet of trestle across the island; then two spans of 164 feet each, one of 250 feet, and a draw 360 feet.; then nearly

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*The bridge was built by the Union Bridge Company. D. M. Wheeler was chief engineer, with George S. Morison as consulting engineer. See Engineering News, October 17, 1891.

5,000 feet of trestle. The total length of bridge and trestle work was about 12,120 feet.

The pier of the draw over Black River is of masonry 27 feet in diameter and resting on piles, while the piers at the ends of the draw are of piles. The five spans over the east channel rested on six masonry piers, the two outside ones are 5 feet wide on top, the others 6 feet, and 22 feet long resting on a grillage of timber 2 feet below water which in turn rested on piles. The up-stream ends of these piers have triangular starlings with a slope of 1 to 1 on the nose. The piers under the west or main channel, except the draw, are 6x21 feet on top, and with the exception of the east one had triangular starlings with a slope of 1 to 1 on the nose, to a point about 10 feet above low water; above that it had the same slope as the batter on the walls—½ inch per foot. The draw pier was 30 feet in diameter on top and 33 feet on the bottom. All rest on a grillage 2 feet thick, two feet below water and are supported on piles. The piles under the main channel spans are 40 feet long and were driven with a steam hammer.

SUPERSTRUCTURE.—The span over Black River was of iron with wooden floor beams; the spans over the east channel and the two short spans over the west channel were single intersection trusses and at that time were the only single intersection trusses over the river except at Louisiana. The draw and the 250-foot span were double intersection.*

All of the spans are still in use except the second short span over the west channel, which was destroyed in a collision in 1882, and was replaced with a Howe truss; this was again replaced with a single intersection truss in 1890, built by the railroad company.

The draw span over the Black River is to be renewed this year (1900).

The trestle across the island has been maintained and was rebuilt in 1886. All but about 270 feet of the west approach has been filled, a considerable part of the east approach over French Slough has also been filled, a portion of it being replaced by a span 163 feet long built in 1877. The total length of the bridge and trestle is at present a little over 5,000 feet.

25 LA CROSSE.

Highway.

This bridge is located directly opposite the city of La Crosse and some distance below the railroad bridge. It was built and is owned by the city of La Crosse. There are two islands in the river opposite the city, the main channel being next to the town. There are pile bridges across the chutes back of the islands and the west one has a pontoon draw in it. This draw has never been operated, and probably never will be, as the chute has been entirely closed to navigation at the upper end by controlling works built by the Government.

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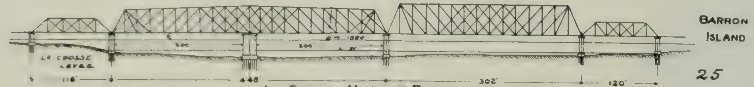
*All were of iron throughout, and were built by the American Bridge Company.



25

LA CROSSE HIGHWAY BRIDGE BUILT 1889-90.

The main bridge, commencing on the LaCrosse side, consists of a span of 116 feet; then a draw span 448 feet long over all with clear openings of 200 feet each; then a span of 302 feet and one of 120 feet. The short spans are Pratt trusses while the draw and the long fixed span are double intersection. The draw is operated by steam and is the only draw bridge on the river used exclusively for highway purposes and it is said to be the longest highway draw bridge in the country. The piers are masonry on pile foundations.*

26 PRAIRIE DU CHIEN.

C., M. & St. P. Ry.

The river at this locality flows at the foot of the high rocky bluffs on the west side. It is divided by a large island, which is below high water with nearly the same amount of water flowing in the channel on either side. The town is on a sand terrace, above overflow, forming the east bank of the river. The total width, including the island, is about 1¼ miles. The current is gentle and the range between high and low water about 22 feet. The act of 1866 authorized a bridge at this point, but it was not built. Before the building of the bridge freight cars were transferred by ferry. In the winter of 1868-69, after the river had frozen over, a pile trestle was erected across both channels of the river and trains ran over it till the ice broke up in the spring when the ferry was again resorted to. This method was continued until 1874, when the first pile and pontoon bridge was completed. It was legalized by act of congress the same year.

In the original structure the approaches and fixed portions across the channels and the island were pile trestles, the opening or draw was filled with a deck barge or pontoon which supported the track, the latter being laid lengthwise with the barge. The barges were 408 feet long, about 30 feet beam and 6 feet deep. The first one had a stiffening truss extending the whole length of the boat and resting on its bottom, later ones have longitudinal bulkheads between the bottom and deck. In opening the draw one end of the boat is kept secured to the fixed bridge, the other is allowed to swing free with the current. It is closed by hauling the free end back to the pile structure by means of a small hoisting engine and a chain lying on the bottom of the river.

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*This bridge was built by the Clinton Bridge and Iron Works, Clinton, Ia.

In the west channel the track on the pontoon was on blocking which was added to or removed, as the river fell or rose, to adjust the track to the level of that on the trestle. In the east channel small changes were provided for by short adjustable sections of track forming inclines, but to provide for greater changes two approaches were built, one for high and one for low water, the latter being submerged at high water. The total length of the bridge was about 7,000 feet. Sheer booms were built extending from each end of the draw opening on an inclined line up stream to the shore. The cost was about one-sixth of the estimated cost of the ordinary draw bridge at the time it was built.*

The original bridges were repaired from time to time as required, and in 1888 were practically rebuilt and in a slightly different position. In 1898 the bridge over the eastern or Prairie du Chien channel was again rebuilt and the location of this part of the bridge was changed to one lower down and directly opposite the portion over the west channel. The portion over the west or McGregor channel is being rebuilt this year. The pile portion of the bridge is of the ordinary kind of this class of structures. The pontoon recently built is 396 feet long and about 41 feet wide over all. It is 6.5 feet deep at the center and the deck has a crown of about 12 inches. It has flaring sides and the floor beams are 6x10 inches and the deck beams of the same size, the sheathing is 4 inches thick, and the deck is 3 inches in thickness. There are three longitudinal bulkheads, those on the sides being 16 inches thick, while the center one is 12 inches thick. The track is laid lengthwise of the boat and is supported on stringers resting on cross beams, made of channel irons, every 12 feet. These cross beams are held against the lateral and longitudinal motion at each end by four 8x10-inch posts which extend from the bottom of the boat, and are bolted to the side bulkheads, to about 20 feet above the deck. They are braced to the deck on the outside and are tied together longitudinally at their tops by a cap running the full length of the boat. The cross beams are free to move in a vertical direction between the posts and the elevation of the track for various stages of water is adjusted by blocking under them, the posts holding the track rigidly against horizontal movement. The stringers at the ends of the pontoon are 36 feet long and slight changes in stage are taken up in their length. A cross section of the pontoon is shown.

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*It was designed and constructed by Mr. John Lawler, who describes it in Trans. Am. Soc. C. E., Vol. XIII., page 67. See, also, Major Warren's report and report of chief of engineers, U. S. A., 1874, part 1, p. 681.

This bridge and the one at Read's Landing are of a distinctly different type from any others on the river, and as such, especially considered as permanent structures, deserve more than a passing mention.

We are led to believe from the description of the original structure that the principal consideration in deciding upon its use was one of first cost, and one conversant with the fate of the ordinary wooden railroad structures would have expected that it would have been replaced with a permanent structure of the ordinary character. The fact, however, that it is owned and operated by one of the most progressive roads in the west, that it has been maintained for 26 years, and that the third structure is being built at this place, would indicate the belief, of the officials of the road operating it, that it is an economical *permanent* structure.

The use of this class of structures is, of course, limited to a very few locations on the river, as it can only be used where there is a gentle current, and where the ice can be taken care of without much trouble. I have not been able to ascertain the cost of this bridge, but it would seem that the first cost should not exceed 20 per cent of that of an ordinary draw bridge at the same point. From the above history it is safe to say that the life of the structure is from 12 to 15 years, which is at least one-half as much as the ordinary so-called permanent structures built at the time of the original bridge. If the annual repairs amount to 5 per cent of the first cost, the total cost, at the end of the 26 years of its life, is still considerably less than that of the ordinary structure, omitting interest charges which at the time of building were very much more serious in amount than at present.

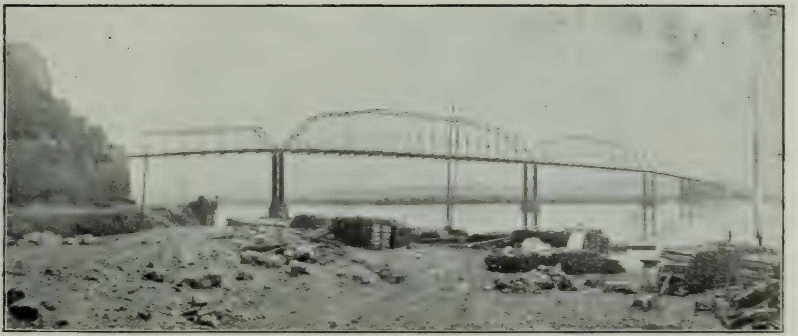
27 EAGLE POINT, DUBUQUE, IOWA.

Highway Bridge—Built in 1901.

This is a toll bridge and was built to enable the farmers in Grant County, Wisconsin, to do their trading in Dubuque. The project has been up at various times for many years past.

In 1894 a bill authorizing its construction passed both houses of Congress. Nothing was done, however, until the summer of 1899, when several different plans and estimates were made. Early in 1900 a new bill passed Congress. Contracts were let for sub and superstructure in April, 1900. Erection was started in July, 1900, and the bridge was opened for traffic in May, 1901.

The bridge has 4 steel spans: two 380-ft., one 200-ft., one 150-ft., and 1,860 feet of wooden trestle. The trusses are 20 feet apart, center to center, and are supported on steel cylinders filled with concrete which rest on masonry piers with concrete interior. The piers rise to a height of 2 feet above high water. The structure is 55 feet in the clear above extreme high water, or about 78 feet above ordinary low water. The masonry piers rest on a timber grillage supported on piles.



Eagle Point, Dubuque, Highway.

The bridge is owned by a stock company composed of Grant County, Wisconsin, farmers and Dubuque, Iowa, merchants. There are no bonds, and the stock is held mostly in very small amounts, the only three holdings of any size being $5,000, $3,000 and $2,000, respectively.

Before bids were asked for, an estimate of cost was prepared and given the directors. This estimate was a little less than $105,000. The total cost, excluding engineers' services, was $97,000. The city of Dubuque, in lieu of making an appropriation, built the west abutment and the west approach. The cost of this is not included in above figures.*

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*This description of this lately built bridge was contributed by the engineers, Messrs. C. E. and R. M. Shankland.

28 DUBUQUE.

Illinois Central R. R.

This bridge, authorized by act of Congress in 1866, was built by the Duluth & Dunleith Bridge Co. and opened to travel in December, 1868. The river at this point flows at the foot of the high rocky bluffs on the Illinois shore. The low water width at the time the bridge was built was 1,700 feet and the high water width about 4,000 feet. The width has been greatly reduced by the encroachments of lumber yards and later by the bridge approaches as will be mentioned later. The current was comparatively slow and the range between high and low water was about 22 feet.

The approach to the bridge from the Iowa side was a high timber trestle 2,400 feet long, part of which was on a curve of about 1,400 feet radius. The first pier stood on what was originally an old levee. The first four spans were 225 feet long, center to center; then one span 250 feet long; then a draw span 360 feet long over all with clear openings of 160 feet; then a span 250 feet long resting on the Illinois abutment.—150 feet back of this abutment was the entrance to a tunnel 835 feet long which is on a curve of about 625 feet radius. The piers were masonry resting on a grillage placed on piles which were sawed off about 10 feet below water where the water was deep enough to permit it. The piers in the water were 24 feet long, 7 feet wide on top, with a batter of ½ inch per foot. About 12 feet below the bridge seat is a band course projecting about 4 inches and below that the up-stream end is finished as a starling with a slope of 4 inches to the foot on the nose.

The horizontal section of this starling is an equi-lateral triangle. The lower end of the piers, below the band course, is semi-circular in plan. The piers are about 43 feet high, 50 feet long by 12 feet wide on the bottom. Rip rap was placed around them to prevent scour.

The superstructure was of iron built by the Keystone Bridge Co. The draw span was of wrought iron throughout. In the other spans the top chords were of wrought iron. The heads and feet of the posts in both the draw and fixed spans are of cast iron. The draw was operated by steam power. It is noticed that this bridge is one of the few built strictly in accordance with the provisions of the act authorizing it.

The draw span was replaced by a new one built by the Keystone Bridge Co. in 1893. The trestle approach has long since been replaced by an earthen embankment. Just when the filling was done I have been unable to ascertain. In 1899, by authority of the Secretary of War, the first span, 225 feet long, on the Iowa side was replaced by a solid earth embankment. The high water area of discharge has, therefore, been reduced from one with an original width of 4,000 feet to 1,535 feet including the obstruction offered by the piers. What effect this reduced width has had on the height of high water above and below the bridge, the velocity of the current, and the scour of the bottom, presents an interesting problem, but it is one that I have been unable to investigate.

The three remaining 225-foot spans were rebuilt in 1899 and the two 250-foot spans are now being rebuilt. The new spans are being built by the American Bridge & Iron Works of Chicago, and have sloping top chords, the center panel only being horizontal. Panels are about 25 feet long. The trusses are built for a single track and are designed for a loading of two 160-ton engines followed by a train load of 4,600 lbs. per foot. It will be noticed that these old spans were in use somewhat over thirty years.

Railway and Highlevel Highway, Dubuque, Ia.

29 DUBUQUE.

Highway.

A wagon bridge was authorized at this place in 1865 and the plans which contemplated a pontoon bridge with a draw opening of about 520 feet were approved. This bridge, however, was not built and nothing was done towards actual construction till the erection of the present bridge, completed in 1887. It was built by the Dubuque Pontoon Bridge Company immediately below the railroad bridge and with the piers in the same line. The two structures are parallel and 75 feet apart, center to center and the draw of the railroad bridge swings under the main channel span.

The structure consists, beginning on the Illinois side, of first, two spans of 120 feet over the tracks of the C. B. & N. R. R.; then a span of 248.5 feet; then a span of about 363 feet which is the main channel span and is 54 feet above the high water of 1880; then a span of 248.5 feet and then 4 spans of 225 feet each. The channel span and two adjoining spans are cantilevers, while the remaining spans are through trusses. The four spans from the Iowa shore, as well as the span on the west of the channel are on a grade of 4 feet per 100, while the channel span has a grade in a vertical curve towards its center from each direction tangent to grade on side spans. The east spans have a grade of 4 feet per 100. The roadway is 18 feet wide in the clear and there are two sidewalks each 5 feet in width. The floor system is of wood; the channel span was erected without the use of false work.

The piers are of masonry carried up to the full height and are 7x24 feet on top except the channel piers, which are 7x25 feet. All have semi-circular ends and a batter all around of ½ inch per foot. The foundations are piles cut off 5 feet below low water, and surmounted by a timber grillage 2 feet thick. The channel piers are about 75 feet high and there are about 150 piles under each pier.*

30 SABULA.

C., M. & St. P. Ry.

Authorized by act of Congress in 1872, and built in 1881. The river in this locality is nearly straight for about three miles above the bridge and flows diagonally across the bottom. At Sabula it flows at the foot of the terrace on which the town is situated. The low water width is not over 1,300 feet, while the high water width, if not confined by the levees or railroad embankments, would be several miles. The range between high and low water is about 20 feet.

The structure, commencing on the west or Iowa side, consists of 82 feet of trestle approach to a span of 160 feet, then a draw 361 feet long over all with two clear openings of 160 feet each; then a span of 259 feet; then three spans of 217½ feet and one of 217 feet to the trestle approach on the island.

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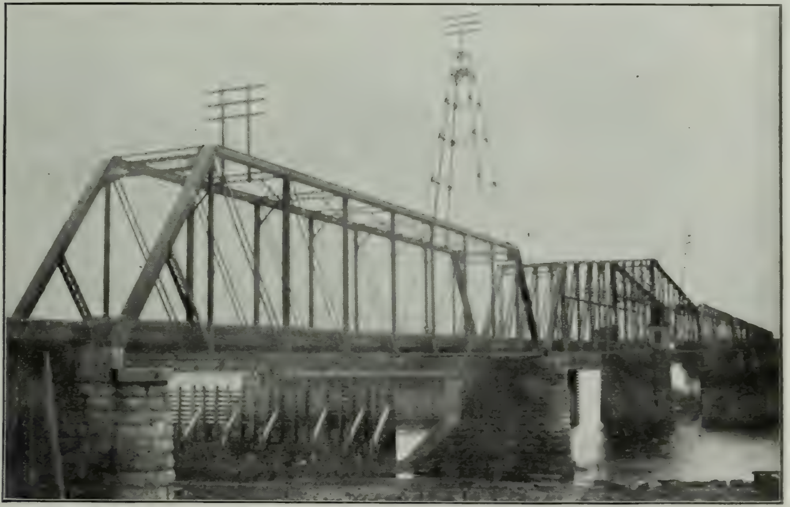
*The bridge, sub, and superstructure were designed and constructed by Horace E. Horton, M. W. S. E., and to him I am indebted for the above information.

This was the first highway bridge across the "Father of Waters" below St. Paul, and marked an epoch in bridge matters, in the fact that the lesser commercial interests of a wagon bridge justified the outlay.—H. E. H.

The piers are of masonry throughout and rest on pile foundations. The piles were cut off at the river bed and the masonry was built in open caissons. The stone is limestone from Anamosa, Ia. The guard piers are rock filled cribs.

It is a single track through bridge; the first span is a single intersection truss, the draw also is single intersection and without counters. The other spans are Whipple trusses. The depth of the fixed spans is 29 feet; the width for the 160 and 217-foot spans is 16 feet; for the 259-foot span 16 feet 3 inches, and for the draw 18 feet. Wrought iron was used for all of the fixed spans. The draw is 25 feet high at the ends and 40 feet at the center; mild steel was used in the bottom chords and it is operated by steam.



C. M. & St. P. Railway, Sabula,

The floor system is worthy of attention; the ties are 6x8 inches and spaced 12 inches center to center, 6x8-inch guard rails shod with angle iron, placed on each side of each rail, while 10x10-inch guard rails are laid on each side of the track and 10 feet 4 inches apart.

The trestle approach over the island is now a double track structure 404 feet long, and was built in 1895-99. There is also a double track pile trestle 458 feet long over the slough back of the island.

Mr. C. Shaler Smith was the engineer, and the superstructure was built by the Edgemoor Iron Company.

A full description of the draw, with details of construction and specifications, can be found in "The Sabula Draw by Graphics," by M. A. Howe.

81 LYONS AND FULTON.

Highway.

This highway bridge was built in 1890 by the Lyons and Fulton Bridge Company, and connects the town of Fulton on the Illinois shore with the town of Lyons (a part of Clinton) on the Iowa shore. Contracts for the work were entered into July 21st, 1890, and the bridge was opened for traffic with elaborate ceremonies July 4th, 1891. It is a toll bridge.

Lyons and Fulton, Highway.

At the site of the bridge, the river is the narrowest for many miles, and the entire flow of the river is at all times confined to one deep channel. The banks on either side are of rock. The river at ordinary stage of water is only about 1,540 feet in width. The towns are almost opposite each other, and the bridge is located so as to make the shortest distance practical between their business centers. The bridge crosses the river squarely and at the Iowa shore the approach is deflected up stream at an angle of 92 degrees with the axis of the bridge.

The structure with its approaches are substantially and permanently built. General dimensions are as follows: Beginning at the Illinois side there is a short earth-work approach not exceeding 200 feet in length. Then three spans of 330 ft. centers of piers; then a channel span 361 feet 6 inches centers of piers; then a deck span 201 feet 6 inches, centers of piers; then a combined pile and timber trestle, and earth embankment about 910 feet in length, and extending up stream along the shore to the foot of Main street in Lyons.

Beginning at the Illinois shores, the grade of roadway rises at the rate of 4.635 per cent; over the channel or 361 feet 6 inches span, the grade is level; thence over the 200-foot span and to the foot of trestle approach the grade descends at the rate of 5 per cent. This gives a clear head room under the channel span of 55 feet above extreme high water level, allowing for the passage of boats at any stage of water. During ordinary stages of water, boats frequently pass under the span adjoining the channel span on the Illinois side.

SUBSTRUCTURE.—The substructures are all of first-class dimension stone masonry, excepting the pier on the Iowa shore; this is an iron cylinder pier and carries the shore end of the 201-foot deck span. The pier on the Illinois shore was founded upon natural bed rock and all others upon piling; the piles were sawed off at the river bottom and surmounted with timber grillage of such thickness as to bring them about one foot below low water level; the grillage for one of the channel piers being 16 feet in thickness. The top and bottom courses of the grillages were made solid and the intermediate courses, approximately three-quarters solid.

The two piers under the channel span are built up to about 5 feet above high water level, and the spans carried by steel towers. The stone is magnesian lime-stone from the well known quarries at Anamosa, Ia., about 70 miles from the bridge site.

Extending up-stream from the pier under the Iowa end of the channel span is a floating sheer boom 700 feet in length, for the purpose of facilitating the passage of log rafts under the channel opening. This boom is made up of several thicknesses of heavy planking, laid alternately in longitudinal and diagonal courses, securely drift bolted together and anchored at intervals to submerged cribs.

SUPERSTRUCTURE.—The superstructure is of steel, with the exception of a few members of iron. The 330 and 360-foot spans are of Pratt trusses, while the 200-foot deck span has horizontal bottom chords, and the top chords inclined parallel with the roadway grade. These is a roadway 18 feet wide in the clear between trusses and one sidewalk, outside of the down-stream truss, and 5 feet in width, with a substantial iron railing. The superstructure was proportioned generally in accordance with Cooper's specifications for highway bridges, and for a live load of 1,600 lbs. per lineal foot for the trusses of 200-foot spans, and 1,200 lbs. for the trusses of 330 and 360-foot spans, while the floor system and secondary members of trusses were proportioned for a live load of 80 lbs. per square foot over the roadway and two 5-foot sidewalks. Only one sidewalk was built, but provision was made for the other at any future time when desired.*

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*The contract for the entire structure was awarded to the Chicago Bridge and Iron Company, H. E. Horton, M. W. S. E., president, on the basis of specifications for the structure prepared by the engineer. Detailed plans for superstructure were later prepared by the contractor, and checked and approved by the engineer. The metal work was all made by the Chicago Bridge and Iron Company.

32

CLINTON, IOWA.
C. & N. W. Ry.

This is one of the very early bridges, having been completed in 1865. The only authority for its construction was granted by the legislatures of Illinois and Iowa. It was legalized by being declared a post route in 1867.

At the site of the bridge the river is divided by Little Rock Island, the main channel being on the Iowa side. The portion over the east channel was built and operated sometime before the part over the west channel, the transfer over the latter being by ferry.

The main bank on the Iowa side is of rock, but not above high water; the island is stratified limestone a little above ordinary high water. The Illinois side is of alluvial formation and subject to overflow. The width of the valley submerged at high water was about 2 miles. The current was gentle, varying from 1¾ to 3 miles per hour between high and low water, and the range between high and low water was about 19 feet. As first built the structure over the Illinois channel consisted of 1,390 feet of trestle approach; then 7 spans of 200 feet each to an embankment on the island. The 200-foot spans were McCallum trusses and rested on masonry piers with concrete cores founded on piles. The structure over the Iowa channel built in 1864-65 consisted, beginning at the island end, of one span 174 feet and one 200 feet of wood, then a draw span 300 feet long over all and consisting of two Bollman trusses suspended by hog chains from a central tower, then a wooden span 128 feet long to the abutment. The trusses were about 6 feet above high water.

The guard pier was originally a rock-filled crib 400 feet long and 35 feet wide, on which the pivot pier was built. The pier at the east end of the draw was also a crib, while the pier at the west end was of masonry. The draw was the first one on the river to be operated by steam power. All the piers except the pivot pier have since been built of masonry resting on piles. The portion of the structure over the Illinois channel was entirely rebuilt in 1868-69. The first span from the east end was replaced with one of iron of the same length. The remaining length of 1,200 feet was replaced with eight spans of 150 feet each, all of iron, the piers rested on piles. The 200-foot span and the two adjoining 150-foot spans were built by the American Bridge Company of Chicago, and of the Post pattern; the next two by the Detroit Bridge Company; the next two by the Phoenix Bridge Company; the next two by the Keystone Bridge Company; the last six being Pratt trusses.

The Howe truss spans over the west channel were replaced in 1874 by iron spans of Whipple trusses built by the American Bridge Works. The draw span was replaced by a pin connected Pratt truss in 1887, built by the Detroit Bridge Company.

The reconstruction of this draw presented some novel features in bridge erection. Owing to the danger of placing false work in the river, the new span was erected up and down stream on the guard pier, leaving the old draw span intact for carrying the railroad traffic. When the new span was completed it was supported by the old span and swung into position in line with the track, the old one then being over the guard pier where it was taken down.

The east 200-foot span over the east channel was replaced by a Whipple truss in 1880, built by Rust & Coolidge. In 1882-85 the eight 150-foot spans over the east channel were replaced by pin connected Pratt trusses built by the Lassig Bridge & Iron Works. In 1898 the 200-foot Whipple truss over the east channel and the three spans over the west channel were replaced by Pratt trusses built by the Detroit Bridge Company, the Railroad Company building the false work. The old masonry was used throughout. Some very rapid work was done in the erection of these last spans, the four old trusses being taken down and the new ones erected between January 19 and February 26. This time does not, however, include time erecting false work. The new spans are 30 feet high and 19 feet 3 inches wide center to center.*

33 CLINTON.

Highway—Built 1891.

This structure starting from the Illinois side crosses the east channel below the railroad bridge just described, and nearly parallel with it. On the island it turns up-stream and crosses the C. & N. W. Ry. tracks, and thence across the main or west channel up-stream from the railroad bridge and at an angle with it The structure consisted, beginning with a trestle approach on the Illinois side, of a span 220 feet long; one 210 feet and six of 150 feet each, across the east channel; then 250 feet of iron trestle to the first river span; then a span of 210 feet, a channel span of 420 feet, which is 55 feet above high water in the clear; then a span of 210 feet and one of 290 feet to the approach on the Iowa across the island to a 290-foot span crossing the railroad tracks side.

The piers in the east channel are steel cylinders filled with concrete, except the first one, which is masonry. The piers in the main or west channel are of stone from Anamosa, Ia., and are carried above high water and the two channel piers are surmounted by iron bents, supporting the superstructure. The bottom chords rest directly on the two side piers. All rest on pile foundations, which were cut off near the bottom of the river and surmounted by a timber grillage. One of the piers was placed in 46 feet of water, the piles cut off about 8 feet from the bottom and a grillage used to bring it up to about 3 feet below low water. The character and arrangement of the superstructure is shown in the profile. The roadway is 18 feet wide with a sidewalk of 4 feet, both inside the trusses.

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*See Railroad Gazette, May 20, 1898, Vol. XXX., page 355.

The west pier of the main span is on line with the draw pier of the railroad bridge and a sheer boom connects them and extends for some distance up-stream from the highway bridge, the west draw opening is thus cut off entirely from use.*

34 ROCK ISLAND.

Railway and Highway.

The original bridge at this point was located a little less than one-half mile above the present bridge, and was built to connect the Chicago & Rock Island Railroad with the Mississippi and Missouri Railroad in Iowa, the latter extending from Davenport to Iowa City, a distance of about fifty-five miles.

The only authority for its construction seems to have been granted by the legislature of Illinois in 1853. The bridge was completed in 1856. The route of the approach to the bridge extended over the island of Rock Island, which was then, as now, owned by the Government as a military reservation. The United States district attorney applied for an injunction to prevent the building of the bridge and approach over the property owned by the Government, but it was denied by the United States Supreme Court, and the bridge was completed. It was probably the worst obstruction to navigation of all the bridges built over the river, but the owners successfully resisted all efforts to have it removed until the completion of a new bridge.

The piers as first built were very weak structures, mostly timber cribs filled with stone, and were not of sufficient weight and strength to withstand the impact of ice, though they were founded on bed rock. They were replaced by stone piers built in 1859.

The structure consisted of 5 spans of Howe truss 250 feet long, and a draw span of about 270 feet with clear openings of 112 and

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*The bridge belongs to the Clinton Bridge Company, and toll is charged. It was built by the Clinton Bridge and Iron Works. George T. Baker was the chief engineer.

117 feet. It was 20 feet above ordinary high water. The trusses had wooden arches bolted to the outside of them. The stone piers were 35 feet by 7 feet wide on top and 53 feet long by 11 feet wide on the bottom. The draw pier was 35 feet in diameter on top and a guard pier of rock filled crib work 355 feet long and 40 feet wide extending above and below it. The piers were not built parallel with the current and were badly located, and in consequence serious delays and accidents occurred to vessels.

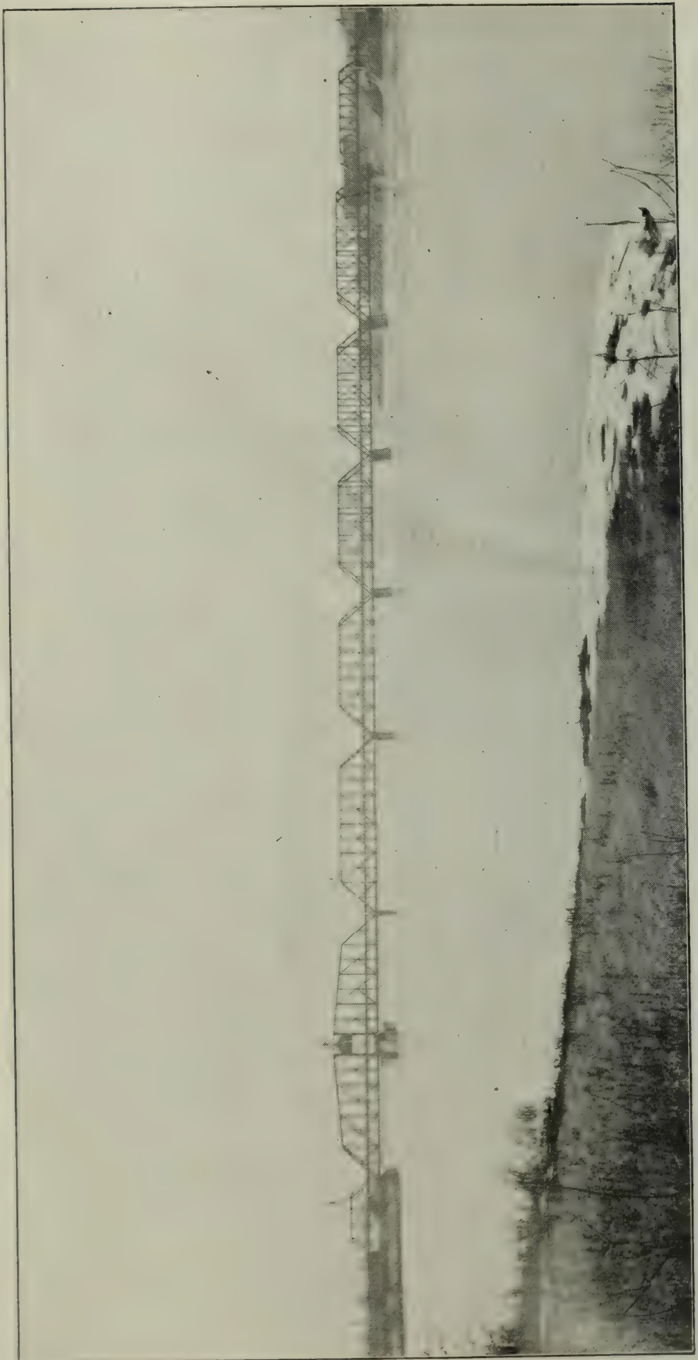
In May, 1856, the first span east of the draw was destroyed by fire communicated by the Steamer Effie Afton. which collided with one of the piers and burned. In the suit for damages that followed Abraham Lincoln appeared as counsel for the Railroad Company.

In 1868 the first pier on the Iowa side was shoved bodily down stream for 20 or 30 feet by the ice, and in April of the same year the draw span was blown over in a wind storm. In the debates of Congress of 1866 Mr. Washburn made the statement that, up to that time, 64 steamboats had been wrecked or damaged on this bridge.

A new bridge was authorized by Congress in 1866, and on its completion in 1872 the old one was torn away. The new bridge was located in the position occupied by the present structure and was built by the Government, partly at the expense of the Railroad Company. During the preliminary work connected with the location of the bridge, its dimensions, etc., various plans were suggested and estimates made of the cost. A notable incident in connection with these estimates was that the engineer who made the estimate of the cost of a structure for a single track railroad with a roadway 17 feet wide below it, afterwards, when a proposition was submitted to him for an estimate on a structure with a 26 foot roadway and a double track railroad, saw no reason for changing his original estimate.

The construction of the bridge was first placed in the hands of the Ordinance Department, but was transferred to the Engineer Department in 1869 and placed under the charge of Major G. K. Warren, who made the plans and retained charge till 1870 when he was superseded by Col. Macomb.

The bridge is situated at the foot of Rock Island, the greater portion of the island being above high water. The width of the river between the Iowa shore and the Island was at that time about 1,650 feet. The channel on the Illinois side of the Island is merely the tail race for the water power at the head of the Island. The location is at the lower end of what is known as the Rock Island Rapids, and the rise between high and low water is about



The New Rock Island Railway and Highway Bridge

16 feet, though this may be increased by ice gorges to 21 feet. The maximum velocity of the current was about 4½ miles per hour.

The bridge was approached, from the Davenport side, by the railroad on a curve of 1,700 feet radius over a span of 196 feet at the intersection of Second and Front streets to the main bridge.

The main bridge had one span of 260 feet, then three of 220 feet center to center of piers, then one of 260.5 feet, and then the draw of 370 feet over all, with two clear openings of 160 feet each. A span of 80 feet then carried the railroad track to the embankment on the island. This embankment extended on a grade of 30 feet to the mile across the island. Then comes a span of 80 feet over the Island wagon road; then the embankment continued 700 feet further to the abutment of the slough bridge. The latter had four spans of 150 feet each.

The piers were built 32 feet long and 7 feet wide on top, the up-stream end had a slope of one to one. The horizontal section of this starling was formed by describing arcs of circles whose radii equal the width of the pier at the section and with centers at the opposite sides. The draw pier was 36½ feet in diameter under the coping with a batter of ½ inch per foot. The upper and lower end of the guard pier was of masonry with the space between the masonry ends and the circular pier filled with rock cribs.

The piers in the Iowa channel are all founded on rock, which lies at a depth of 10 feet to 14 feet below low water. Their construction was let by contract, but owing to inefficient methods employed by the contractor, the contract was terminated and the work finished by the Government by hired labor. The piers in the Illinois channel were of masonry resting on piles.

Superstructure.—The bridge was of wrought iron throughout. The upper chords were of rolled channels and the lower chord of eye-bars in the fixed spans. In the draw span both upper and lower chords were of channels. The draw was operated by hydraulic power, the pumps being driven by steam. The posts were of Phoenix pattern. The railroad track was above the wagon roadway and was attached to the posts. The head room between the two roadways was 12 feet, and both were constructed of wood. The part of the bridge over the Illinois channel, across the island and the approaches were built by the railroad company. The whole was finished and opened to the public in October, 1872. The wooden floor system was replaced with iron in 1891.

The bridge over the main river was built by the Baltimore Bridge Company, C. Shaler Smith, Chief Engineer.

A new superstructure was authorized by Congress in 1894, and $490,000 was appropriated for the purpose. The bridge was built by the United States Government and by agreement 60 per cent of the cost was charged to the C. R. I. & P. Ry. The new spans rest on the old piers and are the same length as the old, all are 29 feet wide center to center of trusses. The draw span is 62 feet high at the center and 50 feet at the ends. The long spans are 50 feet high at the centers. All carry a roadway at the lower chord line with a railroad on the upper deck. The roadway is about 26 feet wide in the clear and carries two lines of rails for street cars. There are two sidewalks each 6 feet wide outside the trusses. The roadway has a clear height of 12 feet 6 inches. The railroad deck is double track; the floor beams are attached to the posts and carry a solid floor of trough sections. The trusses were designed to carry a live load of 100 lbs. per square foot on the roadway and two 125-ton locomotives followed by a train of 4,000 lbs. per foot on the railroad. The wind pressure was assumed at 650 lbs. per foot of bridge.

It was decided to use the old piers, but as the new bridge is considerably wider than the old, it was necessary to lengthen the piers on top. To do this the coping and upper portion was removed to a point where by interrupting the batter of the old cut water and extending it upward and vertically, the necessary length was obtained. The old piers were of Joliet limestone; the new work is faced with Kettle River sandstone with backing of Anamosa limestone, all laid in Portland Cement.

The new turning machinery has some novel features, among them being the connection between the rack on the drum and the operating shaft by means of sprocket wheels and chains with 12-inch pitch instead of the usual gearing. It is operated by an electric motor, power being furnished by the street railway company.

In erecting the bridge the railroad was kept open for traffic except for a short time after the false work and part of the iron work for the new draw had been destroyed by the movement of the ice in the river.*

35 ROCK ISLAND.

Railway.

This is a railroad bridge built for the Davenport, Rock Island

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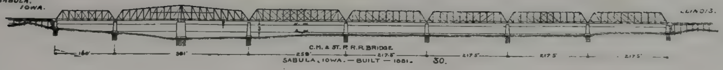
*A detailed description of this accident and the novel means adopted for erecting a temporary bridge, also a more detailed description of the bridge, can be found in a paper by Mr. Ralph Modjeski in the Journal of the Western Society of Engineers, April, 1897, Vol. II., page 135.

The bridge was erected under the direction of Col. A. R. Buffington, Ordnance Department, U. S. A., with Ralph Modjeski, M. Am. Soc. C. E., chief engineer. The Phoenix Bridge Company were the general contractors for the new work.



C.M. & ST. P. R.R. BRIDGE SABULA, IOWA.—BUILT—1881. 30.

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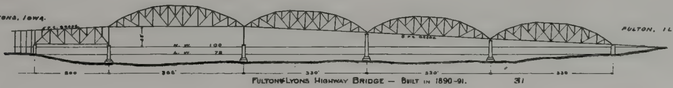
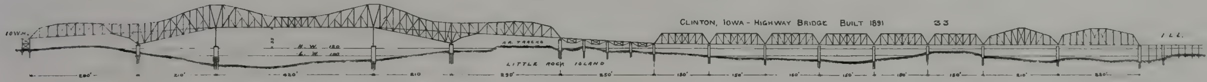


FULTON & LYONS HIGHWAY BRIDGE — BUILT IN 1890-91. 31

31

CLINTON, IOWA - HIGHWAY BRIDGE BUILT 1891 33



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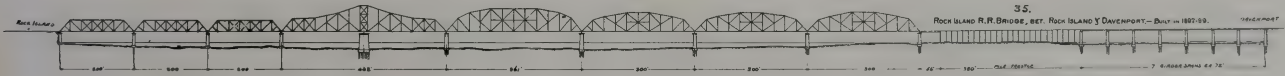
ROCK ISLAND R.R. BRIDGE, BET. ROCK ISLAND & DAVENPORT.—BUILT IN 1897-99.



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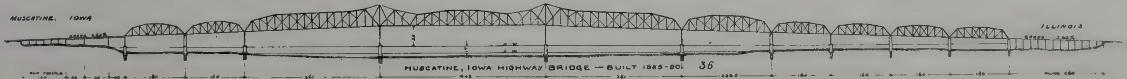

MUSCATINE, IOWA HIGHWAY BRIDGE — BUILT 1889-90. 36

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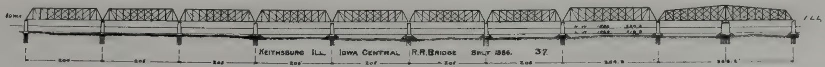
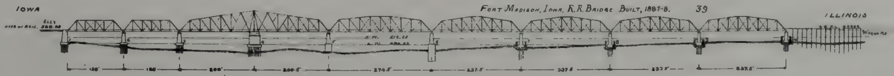


KEITHSBURG ILL. IOWA CENTRAL R.R. BRIDGE BUILT 1886. 37

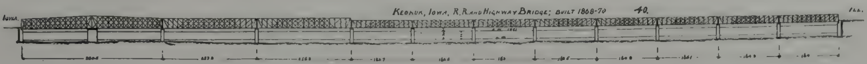
37

FORT MADISON, IOWA, R.R. BRIDGE BUILT, 1887-8. 39



39

KEOKUK, IOWA, R.R. AND HIGHWAY BRIDGE; BUILT 1868-70 40.



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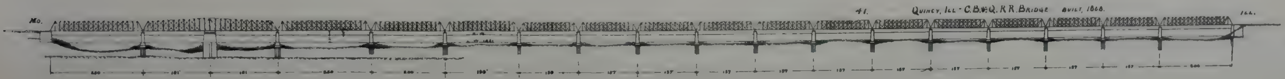
41. QUINCY, ILL - C.B.&Q. R.R. BRIDGE BUILT, 1868.



41

& North Eastern Ry., a belt line connecting Davenport, Rock Island and Moline, and is located about 1½ miles below the C. R. I. & P. Ry. bridge and near the lower limits of the cities of Rock Island and Davenport, and is the last bridge to be completed over the river up to the present time (1900). The main channel of the river is about 2,200 feet wide, from the Rock Island side to an island about 300 feet in width, at the point crossed by the bridge and is below high water. There is a slough about 600 feet wide on the west side of the Island.

Davenport and Rock Island Railway.

The bridge was authorized by act of congress in 1885, but nothing was done towards actual construction till 1895. Work on the portions of the substructure was begun in 1896, but not till 1897 was the construction pushed continuously. It was opened to traffic in 1899.

The structure consists, commencing on the Illinois side, of a viaduct approach over existing tracks and a street, and a short embankment to the main bridge, then 3 spans each 200 feet long; then a draw span 442 feet long over all; then one span of 361 feet; three spans of 300 feet each; one 56-foot girder to a pile trestle 380 feet long across the island; then 7 deck plate girders across the slough to a pile trestle approach. The Rock Island approach is on an 8 degree curve and the three 200-foot spans are on a 7 and 6 degree 30 minute curve, while the draw and remainder of the main bridge is straight. The trestle across the island and part of the spans over the slough are on a 6 degree curve. The curves are all in the same direction and give the bridge as a whole the shape of a crescent. The piers for the main bridge are built of limestone from Stone City, Ia., except the starlings, which were faced with granite. The main piers are 7 feet 6 inches wide and 31 feet long under the coping and have a batter of ½ inch to the foot, and have starlings on the up-stream ends extending to high water with a batter of 9 inches to the foot. The lower ends of the piers are semi-circular. The draw pier is 32 feet in diameter under the coping. The up-stream guard pier is a rock filled crib resting on a bed of rip rap and the up-stream end is protected with old iron rails, the spaces between them being filled with cement mortar. The down-stream guard pier is a pile and timber structure. The piers under the slough spans are steel cylinders filled with piles and concrete. The abutment and first three piers from the Rock Island side rest on solid rock. The other piers are on piles cut off at the river bed. The foundations for the three next the island were placed in open coffer dams, concrete being placed around and over the piles. The three mid-channel piers rest on a timber grillage on the piles.

The superstructure is a single track structure and is of rolled steel throughout, except some minor details. The trusses have inclined top chords except the 200-foot spans which are horizontal. The latter are 23 feet wide, while the former are 18 feet 6 inches wide, center to center of trusses. The draw span is operated by electric motor and all the signal lights about the bridge are electric lights.*

36 MUSCATINE, IOWA.

Highway.

In this vicinity the river flows at the foot of the bluffs on the Iowa side on which the town is situated, and is all confined to one channel. The bridge is a high bridge and used for highway purposes only. Beginning on the Illinois side the structure consists of 260 feet of trestle approach; then four spans of 160 feet each, of which two rest on cylindrical piers; one span of 240 feet, one 360 feet, one 442 feet, one 360 feet, two of 160 feet each, three girders 45, 58 and 55 feet in length respectively and about 120 feet of iron trestle work.

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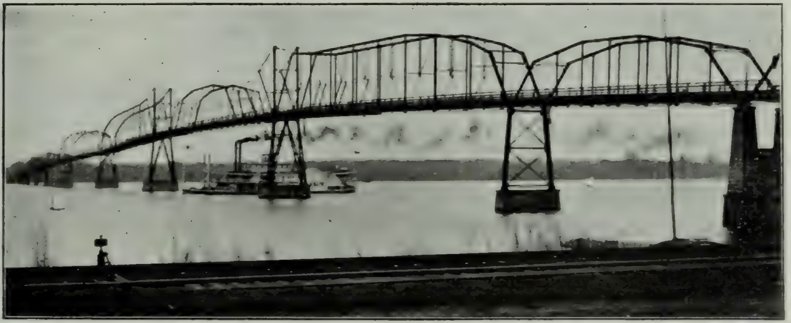
*The engineer was Mr. C. F. Loweth. The superstructure was built by the Phoenix Bridge Company. Mr. Charles Stone was contractor for the main piers, while the slough piers were constructed by the railroad company by day labor. Engr. News, January 11, 1900, contains very full details of the superstructure.

The original plans contemplated masonry piers throughout, but to save expense the first three piers were made of iron cylinders filled with concrete and resting on piles which extend up into the cylinders for some distance. They are respectively 5 feet 5 feet 6 inches and 6 feet in diameter. The remaining piers are all of masonry and have pile foundations. The piles were cut off at the bed of the river and were surmounted by a grillage of 12x12 timbers of sufficient thickness to bring it within one foot of low water except under the two main channel piers, which are 3 feet below low water. The grillage varied from 4 feet to 16 feet in depth. It was caissoned on top, towed to position and sunk into position by weighting with stone. The masonry is of limestone from Cedar Valley, Iowa. Most of the piers are of masonry extending a short distance above high water only, and are surmounted by iron bents which support the superstructure. A few of the piers, as shown in the profile, are of masonry extending to the superstructure.



Muscatine, Iowa, Highway.

The main channel spans are of the cantilever type, while the others are of the ordinary single intersection. The roadway is 18 feet wide with one sidewalk 4 feet wide on the down stream side.*

In the winter of 1898-99 the ice attained a very great thickness along the Illinois shore and in the breakup it exerted sufficient force to move the third cylindrical pier (from the Illinois shore) a distance great enough to let the river end of the second span drop down. Contracts have been let for replacing the cylindrical piers with masonry.

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*Mr. George F. Baker was chief engineer. The Milwaukee Bridge and Iron Works were the contractors. The bridge is owned by the Muscatine Bridge Company, and is a toll bridge.

37

KEITHSBURG.

Railway.

This bridge was authorized by act of Congress April 26, 1882, and built for the Iowa Central Railroad Company in 1886. The river at this point flows at the foot of a low sand terrace which is above high water, on the Illinois side. The banks on the Iowa side are low and the bottom extending to the Iowa bluffs is subject to overflow. The river is divided by a large island, the channel on the Illinois side being the main one. The low water width is about 2,000 feet, while the high water width extends to the Iowa bluffs—some five miles. The structure as built, beginning on the Illinois side, consisted of a trestle approach of 800 feet, then draw span 360 feet long over all; then a span of 255 feet, then 7 spans of 250 feet each, and a trestle of 900 feet. The masonry piers are 6 feet 6 inches by 26 feet under the coping and rest on a pile foundation, which, with the exception of the draw pier, extends above the river and to within about 3 feet of low water. In order to stiffen the pier foundations an open crib was sunk around them and filled with rip rap. The piers have triangular ends extending to 6 feet below the coping.*

38

BURLINGTON.

C. B. & Q. R. R.

This bridge is one of those authorized by the act of Congress in 1866, and it was opened to traffic in July, 1868. It is located near the lower limits of the city of Burlington, Iowa. The river at this point and for some considerable distance above and below flows along the bluffs, on the Iowa shore, which are of rocky formation. The slope of the river at low water was only about 0.27 feet per mile, and in consequence the current was very gentle. The low water width was about 2,100 feet, with a high water width extending from bluff to bluff—about 5 miles. The range between high and low water was about 20 feet.

The structure, as originally built, consisted of an earth embankment on the Iowa side, which was on a curve of about 720 feet radius. Then from an abutment, a span of 175 feet, with a second one of 200 feet. The curve on the approach extended over these first two spans and in consequence they were made wider than the remainder of the bridge. Then a draw span of 360 feet over all with clear openings of 160 feet; then 6 spans of 250 feet each to a trestle approach.

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*The superstructure is of the Phoenix pattern, and was built by the Phoenix Bridge Company, who were also general contractors for the entire structure. Mr. George A. Lederle was the engineer in charge.

The work of the erection of the superstructure was very much delayed by accidents, one of which was the fall of the traveler, used in erecting the second span, and in which three men were killed and five injured. A derrick boat partly loaded with iron was sunk in a gale of wind, and, in addition, the ice carried away the false work for four spans. (Engr. News, December 19, 1885.)

The piers are of masonry resting generally on piles. Piers No. 1 and No. 2 are on rock and were put in with coffer dams. Pier No. 3 had about 170 piles under it; pier No. 4, the draw, about 333. The piles under these piers reached to the rock; pier No. 5 had 174 piles and the remainder from 133 to 140; their lengths averaged from 22 to 32 feet, and they were driven with a drop hammer. The sand was washed out from among the piles after they had been cut off as near the bottom of the river as possible and the space thus formed filled with loose rock. The masonry was laid in floating caissons with bottoms, which formed the grillage, two feet thick and sunk by the weight of the masonry. The sides of the caissons were afterwards removed. The stone came from Lamont, Ill., Point Pleasant, Ia., and LeClaire, Ill., and was laid in Utica cement mortar. The draw pier is 34 feet in diameter at the top and 44 feet at the bottom. The piers at each end of the draw span were 9 feet wide on the top and 19 feet at the bottom. The others were 7 x 23 feet on top, the rectangular part extending down about 10 feet with a batter of 1 inch per foot, where the length increased to 36 feet 10 inches. The sides and down stream end, the latter semi-circular in plan, continued with the same batter. The up-stream end was formed, in plan, by arcs of circles with a radius equal to the thickness of the wall, and with centers at the opposite sides. The nose has a batter of 6 inches per foot.

Many interesting incidents of the construction of the substructure of the original bridge are given by Mr. C. H. Hudson, who was Resident Engineer, in The Journal of Associated Engineering Societies, Vol. 13, p. 257, 1894.

The superstructure was built by the Detroit Bridge & Iron Co. The fixed spans were quadrangular trusses with cast iron top chords, Phoenix posts and bottom chords of open links. Both chords of the draw were of channels and were carried on a wrought-iron drum. This was the first iron bridge completed on the river, though its completion antedates by a few months only the Dubuque and Quincy bridges which were under construction at the same time. In 1887 the first span (175 feet) was removed and replaced by an embankment, the trestle approach to the Illinois side had been filled up some time previous. The entire superstructure was replaced in 1890-93 by a double track structure, with spans of the same length, except the western one (the second one in the original structure) which was replaced by two spans about 71 feet long. The old piers were used, the upper portion only being remodeled to provide for the additional width required.*

39

FORT MADISON.

Railway and Highway.

A charter for a bridge at this place was obtained in 1872 for a proposed railroad from Peoria, Ill. The road, however, was not built and nothing was done towards the construction of the bridge till the extension of the "Santa Fe" system to Chicago was determined on in 1887, when it was surrendered to that company. It was stipulated in transferring the charter that the structure to be built should be a combined railroad and wagon bridge.

The river valley at this point is about two miles wide with rather low banks on either side. The low water width was about 1,350 feet, with a high water width of at least 4,000 feet. No rock was found in the river bed, but on the Iowa side blue clay was found and also formed the bed of the river to about the position occupied by pier No. 4. Beyond that it seems to dip rapidly and is covered with sand.

The structure consists, commencing on the Iowa side, first, of an abutment, then two 150-foot spans, then a draw span 400.5 feet long over all, then a span 274.5 feet long, then four spans 237.5 feet long, center to center of piers, then a trestle approach. The bridge rests on masonry piers throughout, built of stone from Stone City, Iowa. The backing of masonry in the draw pier is concrete. The abutment on the Iowa side rests on piles driven into the clay and cut off about 8 feet below water and about 4 feet below the surface of the clay. Piers Nos. 2, 3 and 4 are on piles cut off at the bottom of the river, which at these points is of blue clay and not likely to scour. The piles are surmounted by a timber grillage 4 feet 3 inches in thickness, which also formed the bottom of open caissons used in laying up the masonry. The draw pier is circular and the caisson was built in the same form. The grillage was carefully brought to a circle at its edge and to this was fastened vertical plank, which were banded on the outside in the same manner as large water tanks; the inside was strengthened with circular braces. The caissons were towed to position and sunk by loading them with concrete on which the masonry rests. Piers Nos. 5 and 6 were sunk through the sand to the blue clay by the use of pneumatic caissons, while piers Nos. 7, 8, 9 and 10 rest on piles cut off about 12 feet below the bottom of the river by means of bottomless cribs. These cribs were built with double walls and the necessary weight given them by filling between the walls with concrete. They were sunk by their own weight and by removing the sand from the area covered by their interior by the use of centrifugal pumps. After the cribs had reached the desired depth piles were driven about 25 feet into the sand below the bottom of the cribs and cut off level and surmounted by a timber grillage of the same thickness used in the other piers. The guard pier for the draw was a pile and timber structure.

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*The details of this work were very fully given in a paper by Mr. George S. Morison, who was the engineer, in the Journal of the Associated Engineering Societies, Vol. 12, page 599, 1893. The chief engineer of the original bridge was Max Hjortsberg. The superstructure of the new bridge was manufactured by the New Jersey Steel and Iron Company, and erected by hired labor under the charge of the resident engineer, Mr. E. P. Butts, till his unfortunate death, and afterwards by Mr. George A. Lederlee.

Ft. Madison, Iowa, Railway.

The superstructure was built by the Union Bridge Co. The trusses are for single track and are single intersection, with long panels and inclined top chords. They are designed for a loading of two 86-ton engines followed by a train load of 3,000 lbs. to the foot; this loading was increased 25 per cent. for the flooring system. No increase was allowed for the loading of the wagon road, as it was thought impossible to bring a concentrated load on the wagon way at the same time the bridge was occupied by a train; the unit stresses allowed in the members were, however, reduced 10 per cent to allow for this increased load. The wagon road is 8 feet wide and is carried on brackets outside the trusses on each side.*

40

KEOKUK.

Railway and Highway.

This was built under act of Congress of 1866 and completed in

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*Mr. O. Chanute was chief engineer, with Mr. W. W. Curtiss, resident engineer. (Engr. News, June 2 and 9, 1888.)

1871. The bridge is located at the foot of the Des Moines Rapids, and the bed of the river is rock. The low water width was, before the construction of the bridge, about 2,600 feet, with a high water width of about 5,500 feet. The slope of the river over the rapids above the bridge averages about 2.2 feet per mile, while in the lower part it is as much as 3 feet per mile. Immediately below the bridge the slope is much less, and the bed of the river is of rock for one mile below the bridge. The average range between high and low water is about 21 feet.

The bridge consisted of 11 spans of the following lengths, measuring from center to center of piers, and commencing on the Iowa side: First a draw span 380 feet long over all, then come spans of 258 feet, 256.3 feet, 162.6 feet, 162.5 feet, 163 feet, 151.5 feet, 164.9 feet, 165.1 feet, 164.3 feet, and 165 feet, making the total length of the bridge 2,190 feet.

The Illinois approach is an embankment, about 500 feet of which is in the former high water channel way. There was a span of 95 feet, which has been lengthened 45 feet over a slough some distance back from the Illinois shore, but with this exception both the high and low water width of discharge was confined to the width of the bridge as given above, instead of an original width of 5,500 feet and 2,600 feet respectively. As the bed of the river is rock it cannot scour, and the height of the water above the bridge must necessarily be increased sufficiently to give an additional velocity sufficient to carry the volume of water.

The Iowa approach was on a masonry structure and on a curve of about 850 feet radius, the abutment being about 160 feet out from the shore line. The bridge is on a straight line and is about 1,000 feet only below the lower lock of the Des Moines Rapids Canal, which was being constructed at the time the bridge was built. The draw pier is on a line with the eastern or river bank of the canal. The piers were built of limestone quarried in the immediate neighborhood, and rest on the rock, though some of them have a timber grillage intervening.

The draw pier was circular and was provided with slots in which the ends of floats, extending from the pier to the guard piers, rose and fell with the water. These floats have since been replaced with a fixed timber structure. The guard piers were detached cribs filled with rock. The piers were built with their axes at an angle of 72 deg. 45 min. with the axis of the bridge, so that the openings between them is not represented by the length of the spans, neither are the piers parallel with the current, thus further reducing the available space. On a trial resulting from the sinking of the "War Eagle" and destruction of a span of the bridge, the legality of the bridge was affirmed in a U. S. Court. Also Report of Secy. War Robt. T. Lincoln, who reports to Congress on legality of the bridge sometime about 1882-83. This available space was only 125 feet in the west draw after the completion of the bridge.

SUPERSTRUCTURE.—The bridge was built by the Keystone Bridge Co., of Pittsburgh. It was of wrought iron throughout, except the head and foot of posts and angle plates of upper chords, which were of cast iron. The trusses are 21 feet high, except the draw, which is about 35 feet high in the center and 21 feet at the ends. The trusses are 23 feet wide from out to out with a sidewalk 5½ feet wide on each side. The floor beams were of two channels trussed and extended outside the trusses to support the sidewalk. The bridge was built for rail and wagon traffic on the same floor, and the whole was planked over at the same level. The draw was turned by steam.

The bridge was constructed without supervision of any officer of the Government and was a marked violation of the provisions of the act authorizing its construction, inasmuch as the piers were not placed parallel with the current, and it did not have two spans adjoining the draw, 250 feet long. The latter provision was, however, impracticable on account of the location of the canal.

In 1883 the eastern long span, or No. 3 from the Iowa end, was rebuilt, it having been knocked down by the Steamer "War Eagle" in the year 1881. The old material was used as far as possible, and the same form of truss was used. The circumstances of the accident to the "War Eagle" are given by Mr. M. Meigs as follows:

"The 'War Eagle,' a side-wheel boat and one of the largest "class employed on the upper Mississippi River, came down over "the rapids at a very high stage of water, being loaded down to "about a 6-foot draft. The current was so rapid that the pilot "was afraid of the east draw opening and attempted to pass "through the opening next the Iowa shore by stopping the boat "and floating her through. Unfortunately the bow of the boat "was caught in the eddy above the bridgealong the Iowa shore, "while the stern projected into the strong current outside the lock. "The result of these two forces was to turn the boat broadside to "the bridge with her stern pointing towards the Illinois shore. "The pilot backed the wheel on the lower side and attempted to "straighten her up, but before he could do so the bow struck one "of the piers and she passed through the raft span broadside-to, "pushing the span off its bearings and allowing it to drop into the "river. The falling bridge razed the guards and wheel from the "lower side of the boat and she floated over the submerged span "and passed on through in a sinking condition. The pilot had the "nerve to stay in the pilot house, and, assisted by the engineers, "managed with one wheel to work the boat to shore some distance "below the bridge on the Iowa shore, where she sank across the "submerged railroad tracks. She was afterward raised and repaired, running for many years on the Upper Mississippi."

The original trusses are still in use and it is the only one of the early iron bridges built under the act of 1866, except the St. Louis bridge, that has not been rebuilt. It has not yet, however, quite reached the age of the Dubuque bridge, the last spans of which are being rebuilt this year. One of the piers is about 6 inches out of line, having been slid on the smooth rock foundation during an ice gorge.

41

QUINCY, ILL.

C. B. & Q. R. R.—Built 1868.

The river in this vicinity crosses the valley to the bluffs on the Illinois side at the town of Quincy, and follows them for about a mile and then flows through the valley with low ground on either side for several miles. The slope at the time the bridge was built was about 0.4 foot per mile, the current gentle and the location of the channel fairly permanent. The low water width was about 3,000 feet and the high water width was several miles, extending from bluff to bluff. The range between high and low water was about 20 feet.

The bridge is about a mile above the old steamboat landing at Quincy, and was built by the Quincy Railroad Bridge Co., under the authority of the act of Congress of 1866, and was opened to travel in November, 1868.

The approach to the bridge from the Illinois side was across Quincy bay, thence across the lower end of an island. Beginning on the Illinois side the original structure consisted first of the bridge of six spans over the bay, then a span of 82 feet, then 85 feet, then a draw span 190 feet long with 80 feet clear openings, then a span of 85 feet and one of 82.5 feet to an embankment 285 feet long, then 400 feet of trestling and an embankment of 670 feet to the main bridge. The main structure consisted of 17 spans as follows:—Beginning on the Illinois side, first a span of 200 feet, then eleven spans of 157 feet each, then two spans of 200 feet, then one of 250 feet to the draw, which was 362 feet long with clear openings of 160 feet, and last a span of 250 feet, which was partly over land. The length of the bridge over the main river was 3,185 feet and over the bay 525 feet, while the total length over the trestles and embankment was 5,068 feet from abutment to abutment. The bridges were on a straight line, while the portion across the island was on a 4 degree curve.

The bridge throughout rested on masonry piers built of stone from Keokuk and Grafton. All the piers in the main bridge except the pivot pier, and all in the slough rest on piles. The pivot pier in the main channel rests on four iron cylinders each 14 feet in diameter 30 feet long. These cylinders were sunk nearly to bedrock by weighting them and dredging the sand from their interiors. They were afterwards filled with concrete lowered in a box and leveled by a diver. The masonry of this pier was built in a water-tight caisson, the bottom of which was composed of three course of timber 12 x 14 inches laid 4 inches apart, and covered with 2-inch plank. The caisson was placed in position over the cylinders and sunk by the weight of the masonry as it was laid up inside of it. The sides of the caisson were removed after the masonry was completed.

The pier west of the draw and the first two east of the same rest on piles, those under the piers adjacent to the draw being driven to rock, while under the other one they were driven about 25 feet. A crib was sunk around the piles which were cut off about 5.5 feet below low water; the top of the crib was about even with the top of the piles, and the space around them and inside of the cribs was filled with rip rap and concrete. A grillage consisting of three courses of timber was floated into position over the piles and suspended by 10 screws 2¾ inches in diameter. The masonry was then laid on this grillage, which was lowered as rapidly as the masonry could be kept above the water. Some of these grillage platforms were lowered in as much as 15 feet of water. From the 6th pier to the east shore, the cribs were sunk before the piles were driven, and the sand dredged from their interior; piles were driven from leads resting on the cribs, sawed off and concrete placed about them.

All of the piers were built of rough ashlar stone facing and backed with concrete. The guard pier is a rock-filled crib connected to the pivot pier by floats. The foundations for the abutments were of concrete, the top being about low water; excavation was made inside a coffer dam.

The superstructure was built by the Detroit Bridge & Iron Works. The fixed spans of the main bridge were triangular trusses, double intersection, with cast top chords and posts of phoenix section and bottom chords of open links. The maximum rolling load was assumed at 2,500 lbs. per foot, allowable tensile strain 10,000 lbs. per sq. inch, and a "compressive strain on upper chords or posts of which the factor of safety shall be not less than five." All the main chord links, main and counter ties, suspension bolts and lateral tie rods were tested in a hydraulic press, connection to the machine being made by pins through their eyes, and with nuts on the screw ends of the bolts, thus putting the strain on the members in the same way it would occur in the bridge. They were strained to 23,000 lbs. per square inch and struck with a hammer while under strain.

The testing of the material for this bridge and that for the one at Burlington, which was being erected at the same time, involved the handling of over 10,000 pieces of finished iron.

In the draw, over the main channel, both chords were rolled channels riveted together and it was of wrought iron throughout. The bridge over the bay was a Bollman truss with cast-iron upper chords and posts; the draw was the same with riveted upper chords and supported by hog chains over a central tower. The trusses were 10 feet high and 10 feet wide, with the track on the top chord.

The main draw span was operated by steam, and that over the bay by hand.*

The trestle on the island has long since been filled. The bridge over the bay was renewed in 1886 by a plate girder structure with the same length of spans. In 1898 seven spans at the eastern end of the main bridge were filled up with an embankment, and in 1898-99 the remaining spans of the main bridge, except the draw span, were rebuilt. The fixed spans are single intersection with trusses 16 feet apart, center to center. The original draw span is still in use, the floor beams and hangers having been renewed. I am informed by a prominent bridge engineer, who recently made an official examination of the bridge, that this span is in better condition than some draw spans built 15 to 20 years later.†

The new bridge is a combined railroad and highway bridge, the highway being provided for on the fixed spans by brackets outside the trusses, giving a roadway 11 feet 6 inches wide from the center of the truss, on each side. Over the draw span the highway runs through on the same floor as the railway. In order to make the turn from the roadway outside the trusses to the one between the trusses, the suspension rod supporting the first floor beam from the end of the truss adjacent to the draw is omitted, and the stringers are made of double the ordinary panel length. The highway is carried across the bay on the old bridge

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*The chief engineer was Mr. Thomas C. Clark, who wrote and published a very complete description of the bridge with full drawings in a volume entitled, "Iron Railway Bridge Across the Mississippi River at Quincy, Ill." D. Van Nostrand, 1869.

† This draw span was rebuilt and completed in April, 1902. The draw span piers and rest piers were remodeled and capped with granite. The new draw span is 358 feet 4 inches long over all. Height at center 55 feet, and at ends 36 feet, with 8 panels in each arm 21 feet 4¾ inches, center to center pins, but the center panel over the turntable is 16 feet. The highway is now carried on brackets on outside of trusses of draw span, similar to the fixed spans.

In 1899 an additional bridge was built across the bay some 4,000 feet below the old one, and consisting of a draw span about 360 feet long over all, and with clear openings of 160 feet; two

An embankment on the island connects this bridge with the plate girders of about 60 feet length connect it with the embankment on the island, while two plate girders of about the same length of span connect it with an elevated structure on the main or Quincy side.

The draw of this structure is a semi-through truss with inclined top chords, and the track about 1½ feet below the top chords at the ends. The truss is 24 feet deep at the ends, and 42 feet at the center. It rests on a masonry pier resting on piles. main channel spans and it is connected by a track, partly elevated, with the main shore end of the old bay bridge. The passenger station is situated on this connecting track and by means of the loop thus formed trains are enabled to cross the bridge from the tracks of the St. L., K. & N. W. R. R. running up the west side of the river to the station in Quincy, and return without reversing their direction of movement.

42 HANNIBAL.

Railway and Highway.

The river, some three or four miles above the bridge, bends to the right from near the center of the valley and strikes the bluffs on the Missouri shore. It is then sharply deflected through an angle of over 90 degrees, and flows along the base of the bluffs to below the town of Hannibal. The river is very narrow and deep, being confined to one channel. The low water width was about 1,500 feet, while the high water width was, before the construction of the bridge, about 6½ miles, being the entire width between the bluffs. By the construction of the bridge and the Sny Levee the high water width was reduced to 1,580 feet. The slope of the river at low water was about 0.4 foot per mile, while the range between high and low water was about 22 feet.

The bridge was authorized by the act of Congress on 1866, and was opened to traffic in 1871. It is located only a short distance below the sharp bend above referred to. It is approached, on the

Missouri side, through a short tunnel on a 9½ degree curve tangent to the axis of the bridge, the latter being at right angles to the stream. The original structure consisted, commencing on the Missouri shore, of first a 250-foot span, then a draw span 360 feet over all, with two clear openings of 160 feet each, then a 250-foot span and four spans 180 feet long to an embankment.

SUBSTRUCTURE.—The first pier or shore abutment was of masonry resting on rock and about 25 feet back of the low water line. The draw pier was of masonry resting on piles, the up and down stream faces being straight and about 21½ feet across in the direction of the bridge, while the sides next the channels were arcs of circles. The width of the pier at right angles to the bridge was 36 feet. The other piers are of masonry resting on a grillage on piles, the piles under the two eastern piers being cut off above low water. The guard pier was a detached crib filled with rock, the space between it and the draw pier being filled with floats which rose and fell with the water. The stone for the piers came partly from Joliet, Ill., and part was quarried in the neighborhood.

SUPERSTRUCTURE.—The draw span was of wrought iron thoughout and the other spans were of wrought iron, except the top chords, which were of cast iron. The 180-foot spans were 22 feet high; the 250-foot spans and the draw at the ends were 25 feet high, the draw being 35 feet at the center; all were 21 feet wide. The draw was operated by steam power.

It is a combined highway and railroad bridge, the floors of both being on the same level. It was built by the Detroit Bridge & Iron Works. It will be noted that the bridge was built in strict conformity with the provisions of the authorizing act, but it presents one of the most striking examples of the effect of obstructing the high water flow of the river. Connections with the high water marks existing at Quincy and Hannibal for 1859 and 1882 by the precise levels of the Mississippi River Commission, show that the contraction of the high water channel, by the construction of the bridge and the Sny Levee, has resulted in raising the high water level above the bridge from 2½ feet to 3 feet. This has again resulted in a very high velocity of current at high water. While the current at low water is only about 3 miles per hour, at high water it is so strong as to be almost impassable by boats except of the most powerful type. In April, 1876, the Steamer "Dictator" with an ice barge in tow was bound up stream, the gauge reading 19.6. She had succeeded in passing the draw when the current caught the bow of the barge, carrying it and the boat around against the west rest pier and the 250-foot span, carrying the latter away. The boat and barge were sunk and nine men were drowned. (Warren.)

The superstructure was rebuilt in 1886 (Robert Moore). The short spans are single intersection, but the draw and the 250-foot spans are double intersection; all have horizontal top chords, except the draw. The old piers were used.

43 LOUISIANA.

C. & A. R. R.—Built 1873.

Authorized by act of Congress in 1871, the act requiring for the first time, on this river, that draw openings should have a clear width of 200 feet. The act was further modified in 1872 and required that the proposed location should be submitted to the Secretary of War for approval before commencing construction.

C. & A. R. R., Louisiana, Mo.

The river in this locality flows along the bluffs on the Missouri shore, and had a width of about 3,700 feet at low water, with a high water width of several miles at the time the bridge was built.

The bridge was constructed by the Mississippi River Bridge Co., and opened to travel in December, 1873.

On the Missouri side the bridge is approached on an embankment on an 8-degree curve, some 450 feet of which was in the low water channel. The first span was 162 feet, then a draw 444 feet long over all, with clear openings of 200 feet each, then a span of 256 feet, and one of 226½, then 6 spans of 161 feet each, to an embankment.

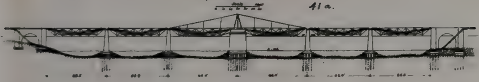
The piers are all masonry, of stone quarried in the vicinity. The west shore abutment rested on piles driven to the rock and was 21 by 4½ feet on top; no grillage was used under this pier, concrete being placed around and over the heads of the piles. Piers No. 2 and 3, for the draw, rest on piles driven to rock. They were sawed off at the bottom of the river and rip rap placed around them. The masonry was built in water-tight caissons and lowered to a bearing on the piles; the bottom of the caissons was a grillage of two courses of 12 x 12 timber. The draw pier was 39½ feet in diameter on top, with a batter of ½ inch. Piers Nos. 2 and 4 were 9 x 25 feet on top with a batter of ½ inch per foot; the upper and lower ends are triangular. These starlings commence at high water, and in plan have a right angle at the nose; the slope of the nose of the upper starling was about 6 inches per foot, beginning about 10 feet below high water and extending to the foundation. These starlings were finished and surmounted by sections of cones and were, as were also the band courses, hammer dressed. The other piers were of the same description except that they were 7 feet wide. The piers beyond the draw pier rest on piles driven about 20 feet into the sand and cut off at the bottom of the river at that time. The masonry rested on a grillage 2 to 3 feet below water. The guard piers were detached cribs filled with rock; the space between them and the draw pier was filled with floats which rose and fell with the water.

The superstructure was of wrought iron throughout except some minor parts. The draw span at the time of its erection was the longest in this country, and it and the two long fixed spans were built by the Kellogg Bridge Co., of Buffalo. The trusses of the draw were 21 feet high at the ends and 40 feet at the center. The posts were two channels connected by an I-beam; these were 12 inches deep at the center, decreasing to 6 inches at the ends. At the center there were two additional inclined posts serving to carry part of the weight to the turntable. The upper chord for two panels each side of the center was composed of open links; in the next seven panels it was of links, channels and plates. The ties were rectangular bars with turnbuckles for adjustment and extending across two panels.

The floor beams were in pairs, one on each side of a post. The 250 and 225-foot spans were 31 feet high and 14 feet wide inside the trusses. The posts were of channels connected by an I-beam; the ties were rectangular bars with eyes and no means of adjustment. These spans were also of double intersection. The short spans were built by the Keystone Bridge Co., and were single intersection, and were 20 feet high. These were the first single intersection trusses built on the river.

As was before mentioned, the piles under the piers were cut off at or near what was the bottom of the river at that time. At the

QUINCY BAY BRIDGE.



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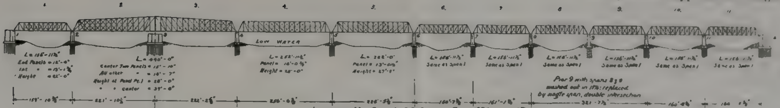

LOUISIANA, MO.-C. AND A R R BRIDGE. BUILT, 1873. 43.

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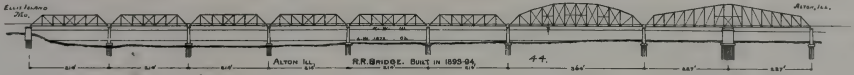

ALTON ILL, R.R.BRIDGE. BUILT IN 1893-94. 44.

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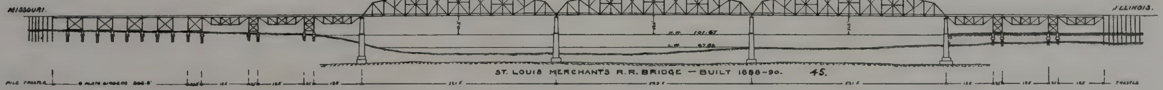

ST. LOUIS MERCHANTS R.R. BRIDGE — BUILT 1888-90. 45.

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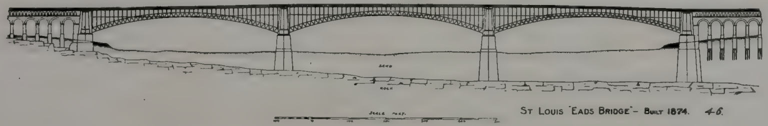

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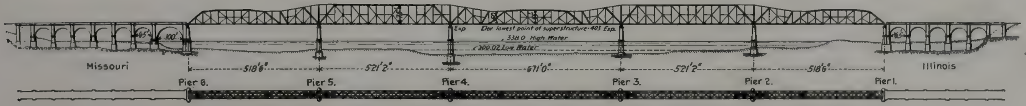
ST LOUIS "EADS BRIDGE"– BUILT 1874. 46.



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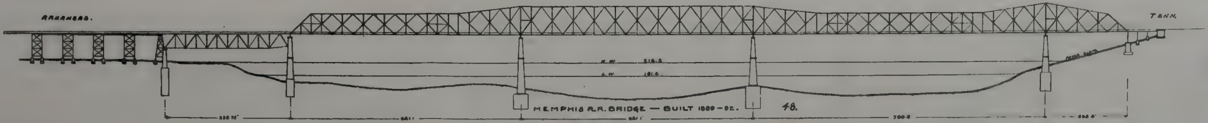

MEMPHIS R.R. BRIDGE — BUILT 1889-92. 48.

48

first high water after the erection of the bridge, the increased velocity, due to the contraction of the high water area by the construction of the bridge and its approaches, scoured out the bottom, particularly under the short spans near the Illinois shore, and in spite of the fact that a large amount of rip rap was placed along the axis of the bridge and about the piers, it scoured out the bottom till at a short distance below the axis of the bridge it was from 23 to 27 feet below the bottom of the piles. On the 6th of November, 1876, the second pier from the Illinois side disappeared, carrying two spans with it, thus illustrating in a forcible manner the risk run in radically reducing the area of the high water flow. (Warren.)

The two spans were replaced by a single span of twice the length, while the material in the short spans was taken out of the river and rebuilt over a slough some three miles east.

The original bridge was rebuilt in 1897-98 by the Lassig Bridge & Iron Works of Chicago, and of the same length of spans; the old masonry was used, no changes being made, except that necessary to accommodate the new bridge shoes. The west span, the draw, the 256 and 226-foot spans were rebuilt, the 320-foot span, which had replaced the two spans washed out, was strengthened but not rebuilt. The last two 156-foot spans were strengthened by "doubling up" the old trusses with the two others rebuilt.

44 ALTON.

C. B. & Q. R. R.—Built in 1894.

This is the last bridge on what is known as the "upper river." It is situated near the lower limits of Alton, Ill., and about 6 miles above the mouth of the Missouri River. The city of Alton is on the bluffs and the channel of the river flows at their foot at the upper and business part of the city. The river leaves the bluff about ½ mile above the bridge and at the bridge there is low ground about ¼ of a mile in width between the low water bank and the foot of the bluffs. The bottom on the Missouri side extends across the Missouri River and has a width of a little more than 4 miles. The range between high and low water is about 26 feet. The low water channel at the time the bridge was built was near the Missouri shore, but the rectification works proposed and being built by the Government contemplated the creation of the channel down the left or Illinois bank, and the draw was located on that side. This explains why on the profile of the bridge the draw is apparently dry at extreme low water.

The bridge is a double track structure consisting, commencing on the Illinois side, of two pile and timber trestle approaches forming a Wye connection with the railroad tracks at the foot of the bluffs, then a draw span 450 feet long over all, with 200-foot clear openings, then one span of 360 feet center to center of pins, and six spans of 210 feet to the abutment on Ellis Island.

The piers throughout are of limestone and rest on pile foundations. The piles were driven by a steam hammer, and were cut off 10 feet below low water with a circular saw, and are surmounted by a timber grillage 4 feet thick. This grillage formed the bottom of open caissons which were floated into position and in which the masonry was built and sunk to a bearing on the piles. The sides of the caissons were removed after the masonry had been brought above the water surface and were used on successive piers.

Alton, Ill., Railway.

SUPERSTRUCTURE.—The trusses are single intersection throughout. The short spans have horizontal top chords, while the 360-foot fixed span and the draw span have inclined top chords. The draw is operated by steam. Total weight of eight spans, 7,856,900 lbs.*

41 ST. LOUIS: MERCHANTS' BRIDGE.

Railway.

Authorized by Congress in 1887 and opened to traffic May 3, 1890. The bridge is located about 2½ miles above the Eads Bridge. The river at this point flows between banks which, without levees, are subjected to overflow on both sides, thus necessitating long approaches on either side.

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*Geo. S. Morison was Chief Engineer. Lewis M. Loss was contractor for the substructure, while the Union Bridge Co. were contractors for the superstructure.

The structure is a double track railroad bridge only, and consisted, at the time it was built, beginning at the Illinois side, of first a timber trestle 1,984 feet long, then a span of 175 feet over the C. & A., Big Four and Wabash R. R. tracks; then 2,580 feet of timber trestle, then two 125-foot spans, then a 123-foot span, then three spans of 521.5 feet, 523.5 feet, and 521.5 feet respectively; then three spans of 128 feet each; 9 plate girders 40.3 feet long; then 547 feet of timber trestle to a 126-foot span over Ferry Street, and a 547-foot timber trestle to an embankment. The main spans have clear openings of nearly 500 feet and are about 50 feet above high water.

The piers supporting the main channel spans rest on caissons sunk to the rock by the pneumatic process; the rock is nearly level across the river and lies at an average depth of 46 feet below low water. The caissons for piers Nos. 1 and 4, numbering from the east, were 26 x 70 feet, and piers Nos. 2 and 3 were 28 x 70 feet, all 17 feet high. On caissons Nos. 1 and 2, cribs of yellow pine 20 to 27 feet high were placed; they were planked with 3-inch oak plank. The space above the working chamber, within the outer walls of the caisson and crib work, was filled with concrete. The first two feet above the roof was of Portland cement, the remainder of Louisville cement. The working chamber was filled with concrete after rock had been reached.

The masonry is first-class "rock face" laid in regular courses. The stone is limestone from Bedford, Indiana, with granite facing from 3 feet below low water to high water level.

The river was reduced to a width of 1,600 feet by building a solid embankment from the east side, above high water and directly under the approach spans. The west end of this embankment is at the east main pier.

The superstructure is of steel throughout and is double track. The trusses were, I believe, the first of long span built on the river with curved top chords, those at Cairo being of approximately the same length, and built only a year or two earlier, having horizontal top chords. The trusses are placed 30 feet apart center to center and are 75 feet high in the center. The double panel length is 57 feet 5 9-16 inches. The trusses are single intersection with intermediate supports to chords and floor system.*

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*The superstructure was built by the Union Bridge Company, E. L. Corthell, chief engineer; George S. Morison, consulting engineer, and H. W. Parkhurst, resident engineer.

46 ST. LOUIS: EADS BRIDGE.

Railway and Highway.

Authorized by act of Congress in 1866 and opened to travel in 1874. The river in the vicinity of the bridge flows at the foot of the bluffs on the Missouri shore. It has been subjected to a great artificial contraction beginning as far back as 1838, and in 1876 the high water channel was only about 1,900 feet wide, with a low water width of about 1,200 feet.

So much has been written concerning this bridge that only a very brief description will be given of the bridge itself. The main bridge consists of three spans with the abutments at about the low water line on each side and with two piers in the river. The spans are circular segment arches, the center one being 515 and the two end ones 497 feet each in length in the clear. At each end of the main bridge spans there are five masonry arches, each of 26 feet span, which cross the wharves. The lower roadway is carried over these arches within an arcade composed of 20 arches supporting the upper roadway.

The foundations of the main piers and abutments all rest on solid rock. The St. Louis abutment was placed by means of an ordinary open cofferdam; the rock being about 13 feet below low water. The others were sunk to rock by pneumatic caissons; the depths below low water being for the west pier 58 feet, the east pier 86 feet, and the east abutment 94 feet. The foundations of the approach spans on the west side are on piles. Most of the masonry is Grafton limestone faced with granite from 4 feet below low water to above high water.

The Chief Engineer was James B. Eads, and his principal assistant was Col. Henry Flad. The foundations and masonry were erected by hired labor directly by the Bridge Co.

Each span is composed of four arch ribs spaced respectively 16, 12 and 16½ feet apart, center to center. Each rib is composed of two members spaced 12 feet apart and in a vertical plane; each member is composed of straight circular tubes, each 12 feet long, 18 inches in diameter, the ends of the tubes butting together and joined by steel couplings. The upper and lower members are braced together by a single system of triangular bracing. A steel pin passes through the couplings at each point and finishes the connections for the bracing and for attaching the support for the floor. The structure is a combined railway and highway bridge, with the highway on the upper deck. The roadways are carried from the upper member of each rib. The upper roadway rests on the top of lattice posts, which rest on the above mentioned piers. The lower roadway is supported by posts or hangers, as the road is above or below the upper member of the arch. The railroad tracks are between the outer pairs of ribs, and are on a 1.5 per cent grade to the center of each side span, and between the latter points is a paraboiic arc.

The position of the track floor is such that at the center of each span the track floor is on a level with the lower member of each rib. Between the points in each span where the upper members begin to rise above the track, direct lateral bracing between the ribs is necessarily omitted. The lower roadway at and just above the ribs was supported by a peculiar construction known as knee braces formed of tee irons; the remaining floor beams were of iron plate girders riveted to posts or suspended by hangers. The track stringers were formed of a pair of 12-inch channels back to back and about 7 inches apart, under each rail; blocks of wood about 17 inches long were supported on small bracket angles riveted to the channels near their lower edge; the whole formed a sort of trough in which the rails were carried without the use of cross ties. The original live load was estimated at 6,400 lbs. for the whole bridge, including highway.

The superstructure was built by the Keystone Bridge Co., under the superintendence of Mr. Walter Katte. It was erected without false work by suspending the tubes from temporary towers by cables and employing temporary anchorages on the banks of the river.

The railway floor was rebuilt in 1888 and is of the usual type of plate girder floor beams and stringers, with stringers riveted to floor beams, and also supported on bracket angles riveted to floor beams. At expansion points, of which there are seven in each span, the bracket forms the whole support for the stringers, which at this end is fastened to the bracket with turned bolts in slotted holes.

Yellow pine ties were used and are spaced 13 inches apart, center to center.*

47 THEBES, ILL.

Railway—under construction—1903.

The Southern Illinois and Missouri Bridge Company, a corporation under the laws of the State of Illinois, was granted authority by Act of Congress, approved Jan. 26, 1901, to construct, maintain and operate a bridge, with approaches, across the Mississippi river, at or near Grays Point, Scott County, Missouri.

This bridge is now under construction, and is situated near the extreme southwest point of Illinois, about 140 miles south of St. Louis, Mo.

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*The new floor was designed by Mr. Robert Moore. The Transactions of the Am. Soc. C. E., Vol. 3, contains a voluminous discussion of this type of bridge. For a full and complete description of the bridge, see "History of the St. Louis Bridge," by C. M. Woodward.

The purpose of the bridge is to form a connection between the Illinois Central and the Chicago & Eastern Illinois Railroads on one side, and the Missouri Pacific and the St. Louis Southwestern on the other, all of which are interested in the bridge company.

The superstructure is composed of two fixed spans, four cantilever arms and three suspended spans, as follows: the central or channel span is 671 feet long and is made up of a suspended span 366 feet center to center of end pins, and two cantilever arms 152 feet 6 inches center to center of end pins. On each side of the channel span is a fixed span 521 feet 2 inches long and lastly are the short shore spans consisting each of a cantilever arm and a suspended span of the length given above.

The structure is a double track one with 28 feet clearance between trusses. The height of the fixed spans is 75 feet, and of the suspended spans 55 feet in the center, and 50 feet at the ends. The height of the bottom chord is 65 feet above high water and 103 feet above low water which is zero on the United States Gauge at Gray's Point, Mo. Only two lengths of panels have been used, namely, 32 feet 6⅞ inches in the two fixed spans, and 30 feet 6 inches in the center spans and the two shore spans. The total length of superstructure is 2,750 feet 4 inches. The superstructure is supported on four masonry piers founded on bed rock.

On each end of the superstructure are concrete arch approaches. The Illinois approach consists of five 65 feet arches, and the Missouri approach of six 65 and 100 feet arches. The piers supporting the concrete arches are founded either on solid rock or on shale.*

48 MEMPHIS.

Railway.

Authorized by act of Congress, approved May 24, 1888. Completed May 12, 1892. This is the first and only bridge built over the lower Mississippi, or below the junction of the Ohio and the Mississippi.

The river below Cairo possesses characteristics different from that of any part over which any previous bridge had been built. The two main tributaries of the lower river, the Ohio and the upper Mississippi, though of approximately the same magnitude, possess entirely different characteristics. The former, though possessing comparatively stable banks and carrying comparatively little sediment, is subject to a wide range between high and low water, while the latter, though subject to less violent fluctuations in stage, possesses all the uncertain elements of a silt-bearing stream. The river, then, below the confluence of these two main tributaries retains the undesirable elements of both: i. e., extreme fluctuations of stage combined with a silt-bearing stream flowing in an alluvial bottom. At Memphis, 232 miles below Cairo, the extreme fluctuations in stage, owing to the greater width of the high water plane, do not exceed the fluctuations at St. Louis, ranging from —2.65 on the Memphis gauge in 1895 to 37.66 in 1897, or a total extreme, as far as observed, of 40.21 feet.

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*See R. R. Gazette, Vol. XXXV., page 20, Jan. 9, 1903, for further details, including some data of design of superstructure and of concrete approaches. The above description of this latest bridge over the Mississippi river was contributed by Mr. Ralph Modjeski, chief engineer, and President W. S. E.

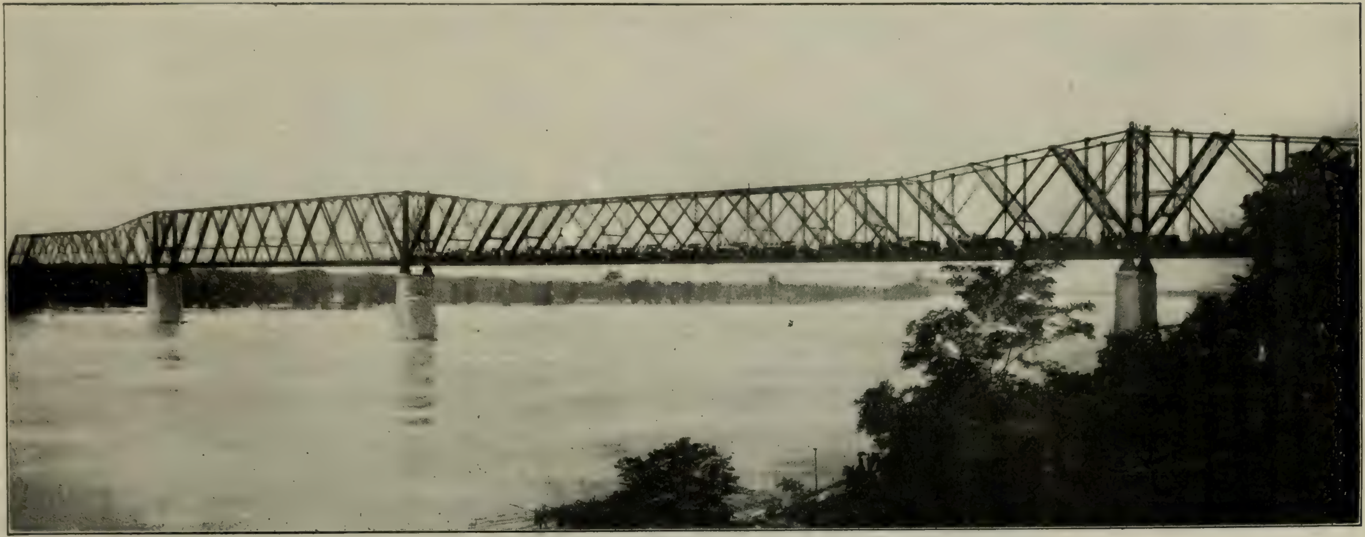
The location of the bridge is near the lower limits of Memphis, which is on the bluffs and has a river front of about three miles. The river above the city flows in a bend along the upper side of Hopefield point, nearly opposite the city, and on leaving the point impinges against the Memphis shore at nearly a right angle. After making this sharp bend, the channel follows down the bluff at some distance below the bridge. The bend on the upper side of Hopefield point has caved very rapidly and thus brought the point where the current strikes the Tennessee shore proportionally farther down stream. Large sums of money have been spent in attempts to check this caving, which between 1876 and 1893 amounted to a recession of Hopefield point of over 3,000 feet. The amount of caving since 1892 has, however, been very small, owing to the efficiency of the protection works.

The act authorizing the construction of the bridge specified that the main channel span should not be less than 700 feet in length, and the others not less than 600 feet, and that it should be 75 feet high above high water, and that it should provide for its use as a highway as well as a railway bridge.

A board of engineers, detailed from the Corps of Engineers, U. S. A., to pass on the plans, location and dimensions, were unanimous in their opinion that the channel span should be adjacent to the Tennessee shore and the majority reported that it should be 1,000 feet long. This report was not approved by the Secretary of War, who ruled that, if the east pier was placed in clear, with two spans 600 feet long in the clear, might be built. (Report Chief Engrs. U. S. A., 1888, p. 2516.) This suggestion was adopted and the structure as built consisted, commencing on spans, the anchorage arm of the cantilever 225 feet 10 inches, the main channel span 790.5 feet, and two spans 621 feet 1½ inch long; then a deck truss 339 feet 8 inches long; then 20 deck plate girders supported on steel towers; then two deck girders over railroad tracks supported on masonry piers, and four deck girders on steel towers to a timber trestle. The latter has since been replaced by an embankment.

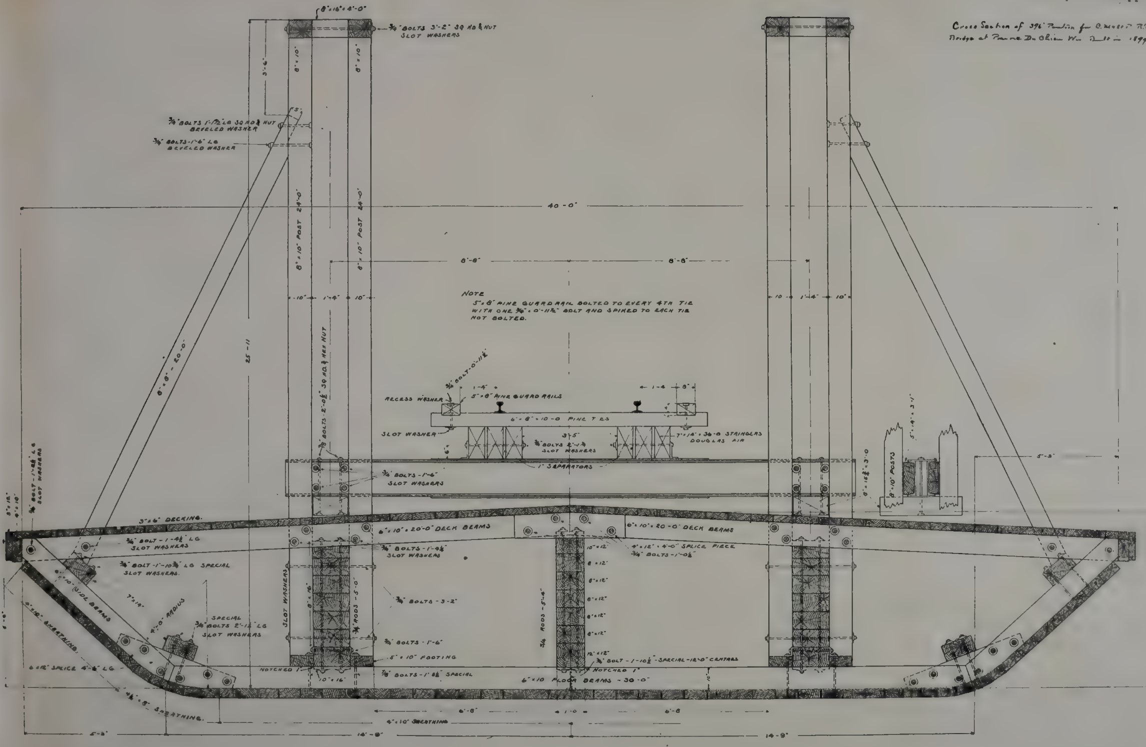
Substructure.—The three main bridge spans rest on 4 piers, two of which are in water 25 to 35 feet deep at low water. The

Memphis Bridge Under Test. A Train of 18 Locomotives.



Memphis—Railway and Highway Bridge. Total length, including viaduct, 4,988 ft. 9 in. Total weight, 19,541,706 lbs. of Iron and Steel.

Cross Section of 396' Pontoon for C.M.&St.P. R.R. Pontoon Bridge at Prairie Du Chien Wis. Built in 1899



PONTOON.

other two piers are near the low water line on either side. The bed of the river is of sand overlaying clay at a depth of 75 to 80 feet below low water at the channel piers, and coming to the surface and forming the bluffs on the east side. The foundations were carried into this clay and were sunk by means of pneumatic caissons, which under piers Nos. 2 and 3 were 92 feet long by 47 feet wide, and were sunk to a depth of about 94 feet below low water. These piers have a total height of something like 175 feet above the cutting edge. A detailed description of the caissons, the methods of sinking them, and the masonry, is found in a paper by Mr. Geo. S. Morison in the Minutes of Proceedings of the Institute of Civil Engineers, Vol. CXIV., p. 289.

The superstructure of the main bridge is exhaustively treated by Mr. Morison in Trans. Am. Soc. C. E., Vol. CXIV, p. 573, and only a very general description will be repeated here. The length of spans between centers of piers is given above. Considering the trusses as a whole and made up of independent spans, the main structure consists of a central fixed span 621 feet in length with cantilevers of 169 feet 4½ inches projecting beyond each end and each supporting one end of a suspended span of 425 feet 8 inches. The opposite end of the west span is supported by the west pier, the opposite end of the east suspended span is supported by a cantilever projecting 169 feet 4½ inches from pier No. 1, and is in turn supported by the anchorage span of 225 feet 10 inches.

The truss panel length throughout is 56 feet 5½ inches, divided into two panels in the floor system. The width is 30 feet between trusses center to center. The depth of truss in the central span and cantilevers is 77 feet 8 inches, and of the suspended spans 56 feet 5 inches. The trusses are pin connected throughout. Expansion is provided for by sliding joints at the ends of the cantilevers and the east end of the fixed span is on roller bearings. The wagon way on the main structure is on the same level as the rails and to provide for it a floor is planked over for a width of 20 feet. At the west end of the 238-foot deck span the wagon way leaves the main bridge and is provided with an independent trestle approach. Owing to the excessive grade on which this approach is built and the very high tolls charged, the wagon way is practically unused.*

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*The chief engineer was George S. Morrison; resident engineer, Alfred Noble. The superstructure was furnished by the Union Bridge Company. It was erected by Baird Bros. on false work, except the suspended span over the main channel, which was projected from the cantilevers to the center. For a complete history and description, see "The Memphis Bridge," by George S. Morison, John Wiley & Son.

THE TECHNOLEXICON.

The Journal of the Western Society of Engineers has presented to its readers the project of the Society of German Engineers to publish a Technical Dictionary under the above title and in the three languages of English, German and French. The Council of the Society of German Engineers and the committee on this work have instructed their editor-in-chief, Dr. Hubert Jansen, to send out a short report of progress of the work thus far accomplished, which is reprinted here in the hope that it may encourage and stimulate to additional efforts in the assistance we can render in this monumental work.

THE TECHNOLEXICON OF THE SOCIETY OF GERMAN ENGINEERS.

In the beginning of 1901 the Society of German Engineers (Verein Deutscher Ingenieure) began the compilation of an universal technical dictionary in the three languages English, German and French. This undertaking has met with general approval and has received assistance from all quarters at home and abroad. Societies and individuals have responded generously to the invitation to collaborate and have proved their interest by the transmission of collections of technical words made by them or by promising such in the near future.

Up to now (May, 1903) there are 341 societies (42 in English, 272 in German and 27 in French speaking countries) co-operating in the work, either by the systematical collection of technical expressions of the specialties represented by them or in other ways, especially by the acquisition of collaborators and by placing technical publications in more than one language at the disposal of the "Verein," as catalogues of firms, inventories, piece-lists of machines, handbooks, &c. Through these societies the Technolexicon has found helpers in Great Britain, Germany, France, the United States, Austria, South Africa, India, Australia, Belgium, Canada, &c.

Among the English societies we name the following: The Institution of Mechanical Engineers, London; the Institution of Electrical Engineers, London; the Junior Institution of Engineers, London; the Society of Chemical Industry, London; the Institution of Mining Engineers, Newcastle-on-Tyne; the Iron and Steel Institute, London; the Society of Architects, London; the British Optical Association, London; the Optical Society, London; the Cycle Engineers' Institute, Birmingham; the South African Association for the Advancement of Science, Cape Town and Johannesburg; &c. Of American societies may be mentioned the American Society of Civil Engineers, New York; the American Society of Mechanical Engineers, New York; American Railway Engineering and Maintenance-of-Way Association, Chicago; the American Chemical Society, Brooklyn; the Western Society of Engineers, Chicago, &c. In Germany there is first of all the large majority of the local sections of the Society of German Engineers; then there are the Verein Deutscher Eisenbahnverwaltungen, the Verein Deutscher Chemiker, the Zentralverband der Preussischen Dampfkesselüberwachungsvereine, the Verband Deutscher Patentanwälte, the Deutsche Schiffbautechnische Gesellschaft, and many others. In France we mention: Société des Ingénieurs Civils de France, Paris; Association Amicale des Anciens Élèves de L'École Centrale, Paris; Société Internationale des Électriciens, Paris; Société d'Encouragement pour l'Industrie Nationale, Paris; Société Française de Photographie, Paris; Syndicat Général de l'Industrie des Cuirs et Peaux de la France, Paris; &c., &c.

Assistance has so far been promised—and partly already rendered—by 2185 industrial establishments and individual collaborators. Among the industrial establishments we mention the Westinghouse Brake Co., London and New York; J. J. Griffin & Sons, London; the W. T. Henley's Telegraph Works Co., London; Fraser & Chalmers, Erith (Kent); Twyfords Ltd., Hanley (Staffs); Sherwin &

Cotton, Hanley (Staffs); Walter E. Mason, Horwich (Lancashire); the Trenton Iron Co., Trenton, N. J.; the B. F. Sturtevant Co., Boston and Berlin; the Thos. D. West Co., Sharpsville, Pa.; Manning, Maxwell, & Moore, New York; the Fairbanks Co., New York and London;—Fried. Krupp in Essen, and the Fried. Krupp-Grusonwerk in Buckau-Magdeburg; the Kaiserliche Torpedowerkstatt in Friedrichsort-Kiel; Siemens & Halske, Aktien-Gesellschaft, Berlin and Charlottenburg; Vereinigte Königs- and Laurahütte, Königshütte (Silesia); Arthur Koppel, Berlin, New York, Capetown, &c.; Gebr. Körting, Körtingsdorf near Hanover, London, and Paris; Blohm & Voss, Hamburg; Elsässische Maschinenbaugesellschaft, Mülhausen and Grafenstaden; Whitehead & Co., Fiume; J. & A. Niclausse, Paris; Panhard & Levassor, Paris; Delaunay-Belleville, St. Denis; Schneider & Co., Le Creusot; Administration des Chemins de fer Paris-Lyon-Méditerranée, Paris; Fabrique nationale d'armes de guerre, Herstal-Liège; Société anonyme John Cockerill, Seraing near Liège; Administration des Mines, Morlanwelz near Mons, &c., &c.

The excerption of dictionaries like Sachs-Villatte, Muret-Sanders, Tolhausen, &c., and of thousands of firms' catalogues and price-lists, of handbooks, store-lists, piece-lists, customs tariffs, &c., has yielded 1,200,000 filled-out word blanks up till May, 1903. To them will be added within the next two years the hundred thousands of words that the contribution of the collaborators will bring. For convenience's sake the Society of German Engineers has provided handy note-books (each with three indices A—Z) for the collaborators to write their collections therein. These books will be called in by the editor-in-chief in the course of 1904. So far already 207 filled-out note-books have been forwarded voluntarily to the office at the address given below.

As the contributions will not be called in before 1904, all who wish to help in the compilation of the Technolexicon have still time and opportunity to assist in the preparation of their specialities. Contributions from all technical branches (including the handicrafts) are welcome, and it is obvious that small contributions from a host of various collaborators will be more useful than large ones compiled by a few men, who naturally cannot cover so many specialties. Attention is to be drawn to the fact that contributions in only one language are also most acceptable, though of course those in two or three languages are the most valuable, as also polyglot business-catalogues and other technical publications. Delayed contributions, if they arrive before the end of 1906, when we shall begin to print, can still be made use of.

The editor-in-chief will be pleased to give any information wanted. Address: TECHNOLEXICON, Dr. Hubert Jansen, Berlin (NW. 7), Dorotheenstr. 49.

LIBRARY NOTES are necessarily postponed this issue, though a number of books have been received for the library.

BOOK NOTES are also postponed this issue, but reviews of a number of books received will be printed in a subsequent issue of the JOURNAL.

WESTERN SOCIETY OF ENGINEERS

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Regular Meeting—1st Wednesday evening of each month except January, July and August.

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Board of Direction—The Tuesday preceding the 1st Wednesday of each month.

NOTICE

From the dues of each member, $2.00 is set aside as a subscription to the Journal.

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Western Society of Engineers.

VOL. VIII. OCTOBER, 1903. NO. 5

CLXXX

RAILWAY MAINTENANCE-OF-WAY.

By H. J. Slifer, M. W. S. E.

Presented May 6, 1903.

Railway Maintenance: "The act of maintaining, keeping up, supporting or upholding, preservation."

It is indeed a simple proposition that has been committed to our tender mercies; but how many sins of omission and commission have been perpetrated under the name Maintenance?

The field is broad enough, if confined to the one class with which we, as engineers, are most frequently brought in contact, and this paper will refer to maintenance-of-way only.

Professor James has raised a storm by his criticism of the lack of technical education of railway men as illustrated by serious congestions that have occurred during the past winter; but technics alone will not move freight nor drive a spike. It is not the intention to belittle the advantages of a technical education as a foundation for a successful railway career; but it is my theory that railway men must be born with a liberal allowance of horse-sense, and this truth applies to the successful engineer of maintenance-of-way and the roadmaster as well as the general officers.

The engineering profession, being associated with the original construction of all railways, is largely responsible for many of the extraordinary expenses of the maintenance department, and this fact should be remembered at all times by the locator and constructor of new lines. The principal subject for consideration being drainage; a slight change in the profile of the original line may be beneficial or detrimental to a good roadbed. Improvements made in drainage by tiling, surface and berm ditches, widening of cuts and embankments, are always good permanent investments. Unless proper precaution is taken in the original construction, it will mean heavy expenditure later to secure results. So much has been written on permanent way, in all its details, that there is "nothing new under the sun" to be said regarding it. We all imagine we know a good railroad, and how to secure it. This paper will treat, therefore, of the means to be used in securing the best talent to obtain the best results with the least expenditure.

We will take a young technical or high school graduate and assign him to a maintenance-of-way corps of men in the field to act as chainman and rodman. After spending one or two years in this capacity, we will appoint him assistant to some competent roadmaster, requiring him to learn, first, the office work, then the field work, and in time advancing him to roadmaster. He should certainly be on a par with his brother graduate whose bent is along the mechanical line, and who having entered some large railroad shop as ordinary day workman, has subsequently been advanced to higher responsibilities, and the same increase of compensation should be maintained. His proficiency should be judged by regular examinations conducted by committees appointed for that purpose, advancement in position and increased compensation being a reward of merit for increased knowledge and wider experience. Suppose we select ten young men and start them out in July; in December, after the field work is closed, call them before a committee of examiners representing the accounting, engineering and maintenance-of-way departments; it will be comparatively easy then to ascertain their practical knowledge, and also to determine which of the ten are worthy of advanced responsibility. In the following July repeat the operation; dropping those who make no real progress. Such an arrangement would certainly entail but little expense on a railway company and would more than pay for the experiment.

In the organization of a maintenance-of-way department, three methods claim our attention, each of these having its advocates.

First, and in my judgment, least practicable, is the plan of placing the work under the engineering department.

Second, and more to be considered, putting the maintenance of track under the control of a general roadmaster, and

Third, which seems to be the exception, rather than the rule, but which certainly works to the best advantage, is, including this work in the duties of the division superintendent. A superintendent has direct supervision over a certain territory. By virtue of his position, and from the fact that most railroad managements concede this point, his authority extends to every department in this district. We all know that definite standards are adopted by the general officers, including the engineering, maintenance-of-way, and others. These standards, in turn, are placed in the hands of the superintendent, and he is or should be, personally responsible. For instance, in the maintenance-of-way department, he, individually, should be charged with items of expense. I have always advocated the superintendent as the one under whose direction this work should come. His immediate staff should consist of a division engineer and a roadmaster. The engineer should be capable of knowing good track, and should also be sufficiently competent to go into the field, and instruct others how to secure the same. The roadmaster should be in his charge, but having direct control of the men employed. Such a system is in a direct line with the training of young men, such as has been advocated earlier in this paper. The line of promotion provides assistant superintendents, then the superintendents. We have the same statement from presidents of roads all over the country, that there is a marked scarcity of men, capable of filling the higher positions, principally from lack of training and experience.

Heretofore, the young man beginning railroad life has had no desire to enter the maintenance-of-way department, because of the lack of a future prospect, seeing nothing higher than the position of roadmaster. In fact, it appears to be beneath the dignity of a technical graduate to be connected with this line of work; at the same time, each year brings scores of applications for positions in engineering corps, almost swamping the files. This condition exists to-day and has given rise to serious thought and consideration on the part of the Roadmasters' Association of America. With the large percentage of foreign labor that is now being employed, the question becomes more serious, and when vacancies as track foremen occur, it is almost impossible to find capable, intelligent men to fill their places.

I would not for a moment attempt to improve on the very able work of Mr. Tratman on the subject of track from an engineer's standpoint; nor would it be possible for me to give any more concise instructions to the roadmaster and foreman, than are contained in the revised "Roadmaster's Assistant," but there are a few fundamental principles that underlie the improvement of track conditions, to which I will refer briefly in closing.

It is to be taken for granted that the modern roadbed is such as has been adopted by the American Railway Engineering and Maintenance-of-Way Association, providing for a width of 20 feet, with an additional space for the necessary ditches. In this connection, we know there is a wide divergence of opinion in regard to ditches; all agree, however, that time, money and attention given to this all-important question is not wasted. Ditches through cuts should be liberal, varying to accommodate the greatest possible amount of water liable to accumulate. On the top of all cuts, where the slope is toward the face, generous ditches should be provided back close to the right-of-way line, and as far from the top edge of the cut as possible, the material from these ditches being banked upon the side next to the track. Generous ditches should also be provided along the foot of all embankments where there is liable to be running water, in every case the outlet of the ditch being diverted away from the adjacent embankment. With a roadbed, as described in general terms and usual standard provided by all railways, good maintenance, which is a synonym for good riding track, can easily be accomplished. There is a difference of opinion as to the amount of ballast that should be provided, but in the writer's experience 12 inches have not proved too much under the tie, particularly when the great amount of poor ballast is considered. Modern railroads are required to use stone, gravel, cinders, burnt clay, dirt and other material, and with the exception of that first mentioned, these different materials are not particularly valuable for ballast.

The question of cross-section of ballast, and whether a shoulder should be provided at the end of the tie is one that admits of considerable argument, dependent entirely, however, upon the character of ballast used. If stone is used, the writer does not think there can be any question but that a good shoulder should be provided, although some writers claim that the friction of the tie on the ballast should be sufficient to keep the track in good alignment. We doubt this to be a fact, however, when we consider the construction of the modern locomotive and car. When gravel is used for ballast, necessary drainage should be provided under the rail, and from the end of the tie. On double track railroads, additional drainage should be provided between the tracks; the reason for this is that ordinary gravel is more or less mixed with sand, and is, to a certain extent, impervious to water.

It has been found that water falling on a double track graveled roadbed will not drain to the edges, but will at times settle into the embankment, causing water soaked, sliding conditions. Burnt clay ballast, if properly prepared, is found to be of such a character as to soak up the ordinary rain storms, and when used, a generous shoulder should be provided, the same as is done with stone. The other materials mentioned need not be referred to at any length.

The railroads of this and other countries are now facing a serious proposition in connection with the supply of timber for ties. Within the past few years many of the western lines have been compelled to use soft wood ties. These, when mixed with the harder oak tie, present an imperfect riding track, even if the softer tie be protected with tie plates. It is believed that cases of broken rails could often be traced to the fact that a number of soft wood ties were in the track adjacent to the joint oak ties. The question of a modern metal tie is one that is engaging the attention of many, and something definite and positive will undoubtedly be worked out along these lines.

Statistics show that while there are many kinds of rail, yet the same general form of rail is adhered to by all railroads in this country. So far as maintenance of track is concerned, the only interest we have in this subject is, possibly, the question of proper method to pursue in renewing rails. There are some things to be said in favor of laying new rails in a string, and there are others just as favorable to the method of heeling in rails one at a time. The question of whether rails should be broken, or laid with even joints is one that interests the maintenance-of-way department. From my experience I am led to believe that there is very little to be said in favor of broken joints, and this particularly applies to the soft roadbed or one that is not properly ballasted. Again the method of laying rails with broken joints must be more expensive, as it requires more joint ties, and even though these do not cost any more money in their original condition, yet the selection of them entails additional expense. While on this subject of joints I believe that it is conceded we are yet far from a pefect joint. There are as many different forms of rail joints as there are inventors, and not being desirous of advertising any particular form, it can simply be said here that a joint which will approximate the strength of the rail is the best one to use.

There can be no question but that the duties of the forces in charge of maintenance-of-way would be much simplified if track connections could be entirely dispensed with, and the fewer frogs and switches there are in a main track, the better opportunity of making said track perfect. I will not attempt to enter into a discussion as to the form of frog or switch, having already taken the position that any frog or switch is a detriment to a perfect riding track, and maintaining them is a source of expense. These however, should be so made as to provide for any emergency failure there might be in any portion of the frog or switch, and the greater the angle of the frog or the longer the point of the switch, the less cause there is for maintenance expense. While on this subject of frogs, it has been the general view that all openings in track, such as frogs, switches and guard rails, should be properly blocked to prevent the possibility of train men being injured. It is surprising, however, to learn that there are professional men who have given this subject a great deal of thought, who take the position that there is less liability of men being injured with an open frog, guard rail or switch, than there is when these are protected, as is usually provided.

With the above general conditions existing on a modern railroad, and the usual liberal allowance to the maintenance-of-way department, the management should expect a perfect riding railroad. The alignment of tracks should be carefully staked out and the necessary easements of curves provided for under some set rules. Permanent markers for future reference and guidance of track men should be established, and each roadmaster provided with the necessary information as to curvature. At stated periods, when ballast is to be renewed, stakes should be provided, those on straight line being set 100 feet apart, and those on curves 50 feet apart. Stakes should be set independently, either for line or grade, on each side of each track to be improved. Those for ballasting should be driven so that a spot board can be laid across the top of them and the track raised to its proper elevation, whether on tangent or curve. When ordinary surfacing of the track is to be done, the section men should be able to raise the track to what is known as running face without any stakes, and even the most perfect track should be raised to a face at stated intervals. There are several things that produce bad riding track, the most important being a defective condition of the joints. If these are allowed to become loose, they produce low joints, wide gauge and if not properly attended to, in time the track will be thrown out of line. Every joint on a section should receive careful attention regularly, and if the bolts in the joints cannot be tightened up sufficiently to keep the splices in shape and tight, then the bolts should be renewed.

Some writers have advocated the widening of gauge on curves, but it is my experience that it is not necessary; and when we consider the coning of the wheels as arranged by the mechanical department, it really appears that anything of this character that is done is useless and opens the door to a custom which must be opposed to the conditions that provide for a perfect track.

The last subject to be considered is that of policing, for no matter how good a line and surface there may be to a track, if the right of way is littered with old ties, scrap iron, etc., and not properly cleaned up, or if the station grounds are not properly policed, the effect of a good riding track will be lost to the eye of the inspectors. To accomplish the desired results along these lines, section men should be required to spend one day a week, at least, cleaning up the right of way and surroundings of all station buildings. This will be time well spent, and the effect will not only be pleasant to the managing officers of the railroad, but also to the traveling public.

In conclusion, it might be said that comparatively few points have been covered in the foregoing article, but it would be impracticable to cover all points that go to make up the different features that must be considered by the maintenance-of-way department, without going into tedious details, in the line of preparing a set rule of instructions.

DISCUSSION.

Mr. A. R. Eldridge One point I wish to refer to is Mr. Slifer's stand that it is not necessary to widen the track on a curve, and that the coning of the wheels provide for that. According to the

Master Car Builders' standard, the gauge of the wheel is 4 feet 8½ inches with a $\frac{3}{16}$-inch fillet on each side, so that the wheel will always grip the rail at a 4-foot 8-inch gauge unless it rides on that little fillet from the face of the wheel where it fillets down into the flange. If that is to be the case and you have your track 4 feet 8½ inches on a curve, I fail to see where your coning does any good.

Some roads put a 4-foot 9-inch gauge and do not widen the curves except perhaps on a curve of 20 degrees, where the engine would not go around such a curve on a 4-foot 9-inch gauge.

I have read of a road in Italy which widened the curve $\frac{1}{16}$-inch for each degree of the curve. Theoretically this would reduce your resistance to a minimum.

Of three roads with which I was connected in the South some years ago, all of them widened the gauge on curves, but I do not think we ever bothered with widening on a curve less than 3 degrees.

Mr. Slifer—Of course there are excessive conditions such as 20-degree curves, where this widening might be necessary, but when it comes to the ordinary curves of modern railroads, I do not believe it is necessary. The objection I have to widening the gauge is the fact that the ordinary section foreman will overdo it. If he is told to widen ¼-inch, for a certain degree, it will be but a short time when he will have it wider than that. If a curve is of neat gauge and the superelevation is perfect, the rail will remain in good condition, without the necessity of widening.

Mr. Eldridge—If you do not widen your curve what good is your coning? If your wheel cannot ride sidewise you certainly cannot take advantage of the coning. Your wheels are coned, theoretically, in order that the outside wheel can travel a greater distance than the inside wheel. If those wheels are the same diameter one has to grind, and your coning, I was raised to believe, was to get rid of that.

Mr. Slifer—I think the variation allowed by the Master Car Builder's Association in the gauge of the wheels will offset all the advantages of coning.

Mr. J. S. Robinson—I would like to ask Mr. Slifer if he does not think that a broken joint is better on a mountain road where the curves are sharp and frequent, than an even joint.

Mr. Slifer—I am somewhat of a Yankee and would like to ask why.

Mr. Robinson—For the reason that it will make a more perfect track; to get the support of the joint tie, well tamped at the center of the rail, and where the curves are frequent it saves the shortening up of the inside rail, and if you have good ballast you get thorough tamping in the center of the rail as well as the joint.

Mr. Slifer—I think my article particularly refers to poor ballast.

There may be very many things to say in favor of broken joints, but the conditions I have been brought in contact with in the last 10 or 12 years have not been perfect. For this reason I have lost my love for the broken joint. I find that the low joint on one side throws the solid rail out of line on the other side, and it is not at all pleasant to get this see-saw motion.

Mr. H. W. Parkhurst—Is it not a very common practice to make broken joints on curves and even joints on straight lines?

Mr. Slifer—Very often. I have followed that practice.

Mr. Robinson—In broken joints on sharp curves many of them have a leeway of 3 feet each side of the center of the rail. I should say ordinarily even joints on a straight track would be better; but under the best condition—good gravel or broken stone ballast—I think the broken joint is just as good as the even joint. It is more economical on mountain roads.

Mr. Slifer—Yet I think Mr. Robinson must admit that there are some lines in Michigan where he would not like to see a broken joint used.

Prof. P. M. Chamberlain—I have noticed, in riding through the tunnels on some of our lines here where the rails have broken joints, that opposite the joint there seems to be a depression worn in the track. I would like to inquire whether that is noticeable in railway tracks—whether the rail opposite the broken joint is worn at that point more than along the general line?

Mr. Slifer—I do not think that would be a fact in a heavy railroad, but I think the track will go out of line at that point, in which case the attention of the roadmaster and others would be called to it.

Mr. F. P. Dobson—The question of broken joints seems to rest on the question of perfect track. It has been my experience that broken joints would answer only on perfect track. I think the same question in regard to perfect track would pertain in regard to the other question of widening the gauge. If we had a perfect track we might not have the cutting of the outer rail and might not have any inconvenience from close gauge. My experience would lead me to believe that a slight increase of gauge would be preferable.

Mr. Eldridge—In regard to coning of wheels, I will give a few figures, which perhaps are ancient history:

The B. & O. has a good many curves, but no coning at all.

The I. C. R. R. in about 1888 coned $\frac{1}{16}$-inch in 36 inches.

The Allen paper Car Wheel Co. $\frac{3}{16}$-inch in 36 inches.

Prosser & Sons put a wheel on the market in about 1886 or 1887 with coning ⅜-inch in 3 feet.

Mr. Parkhurst—It seems to me that the object of coning might be entirely lost under these conditions. We will suppose that the gauge is slightly widened. If a train is going over that curve under strong pull, it is going to hug the inner rail of the curve; you cannot make it climb on the outer one; the coning will in one case work one way and in the other, the other way. I do not think you can count on coning to accomplish just exactly what is desired.

Mr. Slifer—I would like to ask whether any of the gentlemen present have given the question of the run-off and the run-on of the elevation of curves any attention? On a double track railroad I find that the elevation of curvature, which we will presume is to be full at the point of curve, should run off as you go off the curve at a different ratio than it should run on to the curve. That possibly does not agree with theory, but in practice it makes a better riding track.

Mr. W. C. Armstrong—Is there any reason for that?

Mr. Slifer—The only reason I could give is that the car might be more liable to resume its natural position quicker going off the curve than it would be thrown out of its natural position by going onto the curve; or back to its center of gravity quicker than it can be thrown off.

Mr. Robinson—Then you think the easement in going off should be quicker than going on.

Mr. Slifer—Just the other way.

Mr. Robinson—What ratio did you use, increase to the rail length or to the degree of curve?

Mr. Slifer—I run off the elevation at 1 in 60; I run on at 1 in 30.

Mr. B. J. Bernhard—I would like to ask if you used easement on all curves.

Mr. Slifer—Theoretically and practically, all curves should be provided with easements, and vertical curves should be put in at the breaking of every grade.

Mr. F. E. Hermanns—Would you use a different length of easement curve for coming up to the superelevation from what you would use in runnning off?

Mr. Slifer—You would if you followed my suggestion. I would like to hear someone express himself in regard to blocking frogs, switches and guard rails, as I am interested in that.

Mr. Parkhurst—I will say that on our road (the I. C. R. R.) we invariably do it.

Mr. Robinson—Are there not State laws, making it compulsory in many states?

Mr. Slifer—I think so.

Mr. Parkhurst—I do not know about the law, but if the chief engineer finds something that has not been blocked, the roadmaster is very liable to hear of it.

Mr. Slifer—What caused me to bring up this question was the fact that inside of the last thirty days my attention has been called to an old trial where a railroad was sued for the death of a man, in which engineers of standing in this country—some of them chief engineers—have taken the position that there is less liability of a man getting his foot caught in an open frog, guard rail or switch, than when properly blocked. It was a surprising thing to me to have this evidence shown to me, and I thought possibly some of the gentlemen here had heard some of the arguments.

Mr. Parkhurst—It seems to me they must have had a good deal of difficulty in hunting up men to testify in this matter?

Mr. Warder—Was that trial sometime ago, or comparatively recent?

Mr. Slifer Inside of the last five years. Some of the men who gave evidence at that time against the practice are today active chief engineers.

Mr. Parkhurst—Was there any reason given?

Mr. Slifer—Just as I said—it was claimed that a man was less liable to get his foot caught if the frog was open than if it was blocked, as it was easier to get his foot out.

Mr. Robinson—I have known of cases where men have lost a leg on account of frogs not being blocked, but I have never known of a case of this kind where the frogs were blocked.

Mr. Dobson—My experience coincides with Mr. Robinson's remarks. I have known of several cases where people have been killed through lack of blocking, but I have never known of accidents of this kind when the frogs were blocked.

Mr. Parkhurst—It occurs to me that it might be desirable to discuss a little, the question of the bringing up of young men along the proper lines, whether the practice referred to by Mr. Slifer is carried out to any extent, what method of examination is desirable, and so on.

Mr. Slifer—Some years ago the Southern Pacific Railway started out on that problem. I watched the matter with a great deal of interest, because it has been a particular hobby of mine that this is the proper way to bring up young men. I think it was continued for something over a year, when all of a sudden, without anybody ever being able to find out why, the young men were dropped from the ranks entirely and the whole idea was dropped. I particularly refer in my article to the examination held by the accounting, engineering and maintenance-of-way departments. I say the accounting department because I think the young men ought to know all about the accounts with which he may be brought in contact. The method of keeping pay rolls, distributing time, charging out material and everything of that kind out to be a portion of the foundation of the education of these young men. I think he should be a man of some technical knowledge. The examination, as far as maintenance-of-way is concerned, is a practical one whether he knows how to drive a spike, etc.

I will say that the Chicago & North-Western Railway has, to a limited extent during the past two or three years, had a few young men with a good education—some technical and some not—from which they are making assistant roadmasters, and I think some have been made roadmasters. I have watched that method with interest, and while it may be thought that the young men will not take any interest in the maintenance-of-way, I think you can select the right kind of young men who will be glad to go out and rough it and learn from contact the methods to be carried on in the maintenance-of-way department. I believe we are every day extending the theory that the operating officer of a railroad should be a maintenance-of-way man.

Mr. Robinson—Don't you think it would be a good idea also to select a man in a section gang who shows more ability and more intelligence than others, although he may not have a technical education, and make him foreman of the section gang? If you select a number of young men, or one young man in each gang and pay him a little more to make the work more interesting, don't you think that would be a good idea as well as having assistant roadmasters?

Mr. Slifer—Until such time as you can fill up your ranks with these young men, it would be a good idea to select certain men in the gang more intelligent than the others and give them a little more money, and place the responsibility in their hands.

Mr. Parkhurst—I am inclined to doubt the policy of giving them more money, as it tends to make the others dissatisfied.

Mr. Dobson—Do you not think it would be a good plan to give the section foreman a little more money as encouragement in holding good men in the position?

Mr. Slifer—I begin to question whether giving men any more money is any encouragement or not. The section foreman and the section men of this country are without a doubt the poorest paid men on railroads. They receive from $45 to $60 per month, according to the responsibility. Today the various railroads in this district are paying $1.50 a day to their section men, but I want to call your attention to one thing that may have been overlooked: a section man receiving 15 cents an hour will, at the end of the month, receive more money than his foreman. I think the several railroad managements should consider an adjustment of this matter.

I think the most serious thing, so far as railway maintenance is concerned, is the question of making foremen. I have been called on in the last month to organize ten or twelve extra gangs, and I have about reached my limit of securing men capable of handling fifty men. The men that are coming up through section gangs are not making such foremen. I think for that reason it is more important that the subject of making section foremen from these younger men with some intelligence has become a serious matter.

Taking the men Mr. Robinson refers to, I should object sometimes to receiving communications from that class of foremen and that class of roadmasters, for the way they generally "murder the king's English" is something dreadful. But if there is a young man in the section force who is intelligent to the extent of explaining himself when he makes out a report, I believe he ought to be made foreman.

Mr. Warder—You are referring, I suppose, to the average run of men in a section gang, who may not have had a high school education.

Mr. Slifer—Very few have a common school education.

Mr. Warder—How much is it going to help you to get men who have taken a course in the high school and have some intelligent idea of mechanics?

Mr. Slifer—I would start these young men in, and after a while I would examine them with a view of appointing them foremen, roadmasters, etc., and give them to understand that they will be advanced when the proper time comes.

Mr. Warder—Should there not be an age limit in putting men on track work, as men under eighteen would not generally have sufficient strength.

Mr. Eldridge—You will not get a graduate under eighteen years of age, and a great many hit a drawing board for less than 15 cents an hour. Twelve years ago it would have been beneath me to swing a pick and use a shovel. Eight years ago I would not have objected.

Mr. Slifer—The great trouble with you and myself was when we started out we had nothing to look forward to. We doubtless would have used the pick or shovel if we had thought that was the path that led to the President's office. There has been no inducement for the young man to go into the maintenance-of-way department. The other departments have their line of promotion.

Mr. Parkhurst—I think the theory and the practice of the Illinois Central differ somewhat. The theory has been to start in an organization very similar to that described, composed of young men graduates of technical school from eighteen years of age up. The theory at the outset was that these young men would go in as section men. As a general proposition, however, they had not the physical strength and were made chainmen and rodmen, and these young men do that work. So I think these men do not get the experience that it was intended they should. At the same time some of these men are our best men now. They have quite an organization, having meetings at stated times when they read papers, etc., but I think they do not get what it was intended they should—that real muscular experience with track work that they ought to have. I notice now that these young men are pretty sure to act as clerks, chainmen or rodmen rather than going out on a section. In the earlier days they were right in the gang.

Mr. Warder—Why do you say you think a young man going into the roadmaster's department should go into the drawing room first?

Mr. Slifer—I should prefer him to have become acquainted with the accounting department.

Mr. Robinson—Do you not think it would be a good idea for the young man to go into the engineer's office and also take up draughting, so that he may make an intelligent sketch if he is asked for certain information, by his superior?

Mr. Slifer—There will be so much that will appeal to the young man in the engineering department, that he will want to remain there, under the present supposition that there is no future for him on the other side of the road.

Mr. Robinson—After these examinations would you have him, if he is a failure in one line, still continue in that line or would you place him in another line of work? For instance, if he is found, in the examination, inefficient in one line would that condemn him or would you still promote him in some other line in which he might be proficient?

Mr. Slifer—I would simply find out in a general way whether the young man was efficient enough to go on up the line. I would not expect at the end of six months he would be able to be controller or chief engineer.

Mr. Warder—In other words, you want to find out how much "horse sense" a young man has.

Mr. Slifer—It has been said that engineering is three-quarters horse sense and one-quarter technics.

Mr. G. B. Springer—How long do you keep a foreman in his position as foreman? As fast as a vacancy occurs as roadmaster do you make him roadmaster? Also, do you think by breaking in these new men all the time would your track be kept up as well?

Mr. Slifer—In reply to your last question I would say, without any question. They should appreciate the fact that they are there for the purpose of improving the conditions. Their experience and proficiency will determine when it is safe to appoint them as roadmasters.

Mr. Parkhurst—In speaking of the I. C. R. R. I omitted to mention one step in a line not alluded to by Mr. Slifer—that is, under the roadmaster we have on each division, road supervisors who get in the neighborhood of $100 a month, and they are intermediate between the section foreman and the roadmaster. They are, in a way, assistant roadmasters, and they are responsible, to the roadmaster, for the track on their own particular section.

Mr. Dobson—Is it not a fact that few of the railroads have adopted this line of promotion from maintenance, to the exclusion of the old method of promoting telegraph operators?

Mr. Slifer—The only one I know of is the Pennsylvania R. R.

Mr. Parkhurst—I think we can count up about five division superintendents that went up through the engineering department.

Mr. Slifer—To give you some idea of the maintenance-of-way question, and the seriousness of it, I know of a railroad where for years the superintendents were nothing more nor less than trainmasters. Suddenly a reorganization took place; matters of maintenance-of-way were placed in the hands of the superintendent and they were completely lost. I think it is a very serious mistake for a superintendent not to know something of maintenance-of-way matters, and I want to say it does not require technical knowledge.

ADDENDA.

Mr. Tratman—As to coning of wheels, all car wheels are now made to conform to the standard tread and flange of the Master Car Builder's Association. The coning is $\frac{1}{16}$-inch in 2⅜ inches. Engine wheels are sometimes set to a different gauge to allow for curves. Thus, consolidation engines may have the front and back drivers 53 inches, back to back, and the second and third drivers 53¼ inches. I think it is general practice to widen gauge on curves, but there is no uniformity in the practice.

CLXXXI

RAILROAD RECONNAISSANCE.

By Willard Beahan, M. W. S. E.

Presented June 3rd, 1903.

Reconnaissance is to railroad location what scouting and skirmishing is to an army. It learns what difficulties are to be met, where these obstacles lie, and gains a knowledge of the field of operations, while spying out the vulnerable points of attack. An eye experienced in the work, a good memory for localities and lay of the ground, and a clear judgment are the personal equipment needed. There is nothing marvelous about it. Brilliancy is dangerous in reconnaissance, save that clear insight that comes to steady workers after exhaustive study of a question. There is not a particle of guesswork about it, finally. But one may surmise a solution provided he at once follows that solution through and makes sure that his surmise is based on fact. There are no short cuts to good reconnaissance. "Points" will not aid you, though given by the best of reconnaissance engineers. Nature is always original and topography is seldom repeated. Nature will not be cheated. Never try to trick nature nor fool a crowd of boys. Never expect to make a railroad reconnaissance by any method except honest, capable work.

There are a few principles and a few methods of work which experience may hand down to inexperience. All the rest is practice and patient study. We may divide the work into two classes as the objects are distinct:

First. Reconnaissance for Route.—This is to insure that the best route be found for the road, and that the outlay of capital be guided into the channel where the highest rate of interest on the outlay can be secured.

Second: Reconnaissance for Line.—This is to so locate the railroad in the route found and chosen as to adapt the curvature and gradients to the topography in the best possible manner. Or, in a word, to find the best line in that route where first cost and cost of operation are each duly considered.

The reconnaissance for route is the more general, covers more breadth of country, and is to railroad location what strategy is to war. The reconnaissance for line is more specific, covers a narrower belt of country, and is to railroad location what tactics are to war. We will consider each in the order in which they would be undertaken in applying them to the work of a line. We will assume in outline a case as it would naturally present itself to a locating engineer of a railroad company or the chief engineer of such company, who is in the habit of doing his own location work. Let us assume that the president of the railroad company contemplates a new line, to form a part of the system he now operates. To decide whether such new line be desirable, he writes the chief engineer a letter, of which the following may be an outline: "We contemplate building a line from A to Z. I wish you to examine the country between these points and see what kind of a line we can get. Go over the ground carefully and make an examination and let me know what you find, together with your recommendations. We want to leave A in such a way that the present yards and depots may also be available for the new line. We should reach the river at Z at some point suitable for a ferry for present use, and at the same time be so situated that we can reach a good site for a bridge at that river in the future. As to the line between the initial point and the terminal point, much depends on what difficulties are met. We should pass through the town of G, unless the obstacles met increase the cost more than their business is worth. The mines at H you will also consider. They are a little out of the direct course, but no doubt their output will be found to warrant the divergence. We can cross the K. & L. R. R. at grade if we choose. The M. & N. R. R. we must either go over or under. Lose no distance except for good reasons. As soon as I get your report upon this examination I will advise you whether or not survey is to be made, and what plan we will try to carry out."

On the receipt of this letter just quoted, and written by the president, the chief engineer may undertake the reconnaissance or send a locating engineer. In either case the man who goes becomes the locating engineer for that reconnaissance work, and is now to start a reconnaissance for route. The first thing needed is the largest scale map and the most correct and complete one for the entire region. It must cover the territory from A to Z and extend laterally each way from a straight line, so that the map shows the country fully for ten miles outside where any preliminary will go. This map should be mounted on cloth and folded to go into a saddle pocket or a small satchel. Often, one must get a part of the map in full detail at local towns on the route. This map is a tool and not a record for the survey, and must be used without sparing it. Most states have maps of one inch to six miles. County maps are much larger and are indispensable. The instruments needed on a reconnaissance for route will vary with the custom of the engineer making the reconnaissance, but in general the following are required: Prismatic compass, aneroid barometer, binocular level and field glasses. For platting, a rectangular shaped protractor and a triangular scale six inches long are sufficient.

The prismatic compass should be as portable as possible. The kind having the forward sight shaped as a top cover of the compass and closing up to go into the second watch-pocket of the trousers is convenient.

The aneroid barometer need not be large, but must be a good one and recently tested by a reputable firm for such work. One graduated to feet on a circle which is movable, as well as another circle which is fixed and graduated in inches, has some advantages in the field. Beyond a doubt it is well to have a second barometer, or a barograph which will self-register, kept in camp or at the last stop, and registered so that the barometric changes due to weather can be eliminated from the final reading. Where possible to so arrange this, it saves time and risk. With one barometer the usual safeguard is to repeat the reading of the same point at different times. An aneroid barometer must be neither implicitly believed nor obstinately ignored. It is useful but often misleads and is seldom precise. One common error is that it drags in its readings. As you steadily travel, the aneroid reads at the elevation where you were some fifteen minutes ago. One should *wait* before reading. Of course, always read it while holding it level and face upward, lightly tapping the glass with the finger before reading and looking directly down upon the index.

The binocular level is comparatively modern. It looks like a pair of fairly large opera glasses. One barrel is made like one-half of the opera glass, but the other barrel is blind at the object end. This second barrel has a horizontal cross hair and a level bubble tube just inside and at the top of the barrel, with an aperture for the light to pass into the barrel at the middle of the bubble tube. As you use the glasses you are unconscious of its construction. This level is a hand level with magnifying power and better definition. It checks aneroid readings in heavily rolling prairie country, and is of less use in wooded country or on long slopes.

The field glasses need no description except to say that a pair that can be adjusted to the distance between your eyes is the best. These glasses should be cool to the eyes and have no chromatic aberration. This quality will largely prevent running into a cul-de-sac (a bugbear of reconnaissance), for the more distant ridges will show a different color, as they should.

Finally, having the map and instruments, the transportation is alone lacking. If we can make the reconnaissance on foot, it is best. Usually the distances to be gone over prohibit this. Practically, in my judgment, the ideal way is to make the reconnaissance for route on horseback, but go over the rougher parts on foot. In a civilized country with regular roads one needs no guide or companion. In wild country a guide is needed. In an unsettled wilderness a pack train and a packer or two, one of whom shall be a camp cook, are necessary. It is needless to say that the whole question of transportation on reconnaissance work is a very important one, but varies with circumstances. Proper transportation for a prairie country is useless in a timbered country, or in the steepest of mountainous country. But whatever the country, the transportation must be adapted to that country and be ample and efficient.

The kind of transportation, however, must not be confused with the question of the transportation of a certain man or a certain kind of man in that country. We must assume here that the man who is to make the reconnaissance is adapted to the work and country, and needs for himself no special way of traveling. It is my judgment that a man for reconnaissance must be as good a walker as a company officer of the infantry of our regular army, and as hardy a rider on horseback as our cavalry officer, while for sleeping and eating he should be able to get along with that suited to a government scout when that scout considers himself living in comfort in the field. A man on reconnaissance must walk where walking is best for his duties, and ride where riding is best. If I may be allowed to quote my own experience here, I would say that for long, fast, first trips over the country, I prefer a double team and a driver who is a guide; in camp and for regular reconnaissance of a usual sort, I prefer a saddle horse of the class our cavalry uses, and when the country forbids all this, I walk. But a horse can be used to some extent in almost any sort of country. It is a rule of our cavalry service that one can lead a horse over any ground except where the hands are needed to help one to move.

A double team is, in my experience, good for about fifty miles a day; a good saddle horse for about thirty-five miles a day; while one can walk twenty miles a day. Use the transportation by preference that can take you over your ground the fastest.

In my judgment, the first principle of railway location is this: Never depart from a straight line between the successive controlling points laid down in your letter of instructions, without a sufficient economic reason for so doing. Therefore, the first step in reconnaissance for that line is to carefully draw on the map you are to use, a straight line through the successive controlling points given in the letter of instructions by the president. Follow this line on reconnaissance and never leave it unless forced from it by country too difficult for the class of road to be built. In short, you *have authority* for following this line of the map just drawn, but you *must justify* your variation from that line. This principle needs, to my mind, no justification, but from my observation, there are many location engineers who violate it. For this reason it will happen that the lines located by some of us can be shortened and reduced in cost at the same time.

The direction of the first course of the reconnaissance, viz.: from the initial point A to the next controlling point B, must be taken from the map. The bearing of the course or the angle it makes with land lines or track must be measured on the map and the course from A to B fixed on the ground. Then read the prismatic compass as it is sighted along this first course, record the reading, and fix two objects ahead on the line and have them as far apart as possible. Record the reading in notes and on the map and extend the initial course to the end, using two objects ahead where you can, for they keep the line more closely than the compass reading will do.

For the levels, use the elevation of the track at the initial point if you have it, and continue in that system of levels there found. Or, get the best information you can and start with that, carefully noting what you assume. Set the sliding circle of the aneroid barometer so that the index will read there the right elevation in feet for the initial point. Then notice where the zero of this sliding scale is with reference to the fixed circle marked in inches, as usual. This is necessary, for the one circle may move by jolting. If the weather is disturbing the barometer much, you must wait or get another reading at a later date, meanwhile using a temporary reading for the day. An unsettled barometer cripples reconnaissance; a fog stops all work; a snow storm is worse than a rain storm. It is a good plan to read the needle of the ordinary compass on each long course of the line, so as to check the prismatic readings. It is well to use the binocular level to check the aneroid barometer. Never follow any one pocket instrument implicitly. They are not instruments of great precision. They are being jolted constantly. The men who tell tales of their great accuracy and constancy are careless men, at least, and may even be guilty of poetic license.

As you travel exactly along the first course, if the country will permit, note the elevation at each valley and ridge and the distance between readings taken. If the map does not give the distance, nor the section lines enable you to get the distance, the wagon wheel can have an odometer attached or you can time your horse after knowing his speed, or time yourself as you walk. Elevations without distances are of little value.

The second principle of railroad location is, in my judgment, that the direction of the drainage of the country is the frame work on which to hang your line. The first thing you need to know, after getting your course for the reconnaissance, is the direction of the drainage and how that drainage is related to the other streams of the general region. You can never know too much about that drainage. Study it incessantly. Drainage direction is the skeleton of topography, and a man who does not know topography, whether he can map it or not, should not attempt reconnaissance. Which way does the water flow? What creek does it flow into, and where does that empty into a river? These are all questions that will not down on reconnaissance. Put each stream on the map if not already there.

Having got the right direction and gained a general outline of the drainage, continue the work of reconnaissance until country is met so difficult that you are justified in departing from the straight line from A toward B. Locate that obstacle carefully. Is it a hill? Where is it, how high is it, what is its lateral extent each way from the line to left and to right, and on which side of it and how far from the direct line should the line run at that point? Is it a stream, and your direct line strikes a bend lengthwise or at a bad crossing? Then look each side of the direct line for the nearest good ground on which to cross well. Locate this point and fix the distance on the map. Then draw a revised line on the map from this new point to B. Then reconnoitre this new line. Do not come back to the line from A to B until B is reached. At some other time, if not on your return to quarters that day, look carefully along the line from this new point back to A.

On reaching the point B, turn off in the field with the prismatic compass the angle shown on the map between the line AB and the line BC, and so continue the reconnaissance to the terminal point.

In general, take every note needed and not a single note more. Most of us take too few notes. Some try to take too many notes and fail to do it. A field man who does not know how many notes he needs is lost. Read an aneroid at as many different times as you can on the controlling points on divides and stream crossings. Use field glasses whenever you can get up high enough for a wide horizon. On steep hills when not too long and where the height of that hill is important, run a line of hand levels. You need no rod. In any event, at these controlling hills do not fail to note the height or rate of slope from the top as well as from the bottom when using the eye. It checks the eye and will save serious blunders, as eyes differ. My own see a level plain as a saucer. I overestimate a hill from the bottom and underestimate a hill from the top. On reconnaissance, I like to start from the top and work down, but just as soon run a preliminary up hill as down. Usually, locating engineers, I think, prefer to start at the top and work down a hill. Some companies instruct their parties when approaching a long ascent to drop the line and go to the top and run down back to a connection. There is some reason for all this in our human construction.

On reconnaissance for route we must examine every question touched upon in the instructions. Do not fail to make your report answer the questions your instructions ask. Besides the topographic features, one should not forget the traffic considerations, even if not mentioned in instructions. Railroads are not built to show the expertness of locating engineers, but to get business. In short, find out all you can that would interest you if you owned all the stock of the road as well as were engaged on reconnaissance for route.

We will assume that your report, after making the reconnaissance for route, is of such a nature that the president decides to run the necessary preliminaries and locate the road. There is then to be made a reconnaissance for line. This must determine and show both on the map and on the ground where the preliminary or each preliminary in turn shall be run. In former times the reconnaissance for line was often made by the whole party. "Trial" lines were run. "Spur" lines were started from the direct line at an angle of about thirty-five degrees "just to see what would be found." Our country now shows in its wooded portions many lines so run. It was expensive and slow. It may have been begun when Indians were dangerous. It is the extreme of bad reconnaissance.

Reconnaissance for Line is for the purpose of saving the running of preliminaries, and so far as practicable, to avoid them. It is examining all routes which may be feasible for a preliminary, and selecting one or a few of them which shall surely include the best line the country affords. It is running preliminaries without a party. It is finding *all* preliminaries at all promising, and condemning those of least promise until few remain. A good locating engineer needs to run fewer preliminaries between two points than a poor locating engineer needs to run, in order that each finds the best line upon which to locate. Reconnaissance for line is to find the best line every time and to save running preliminaries without missing that best line.

The equipment is the same as for reconnaissance for route, but you work from camp or from the town where the party boards. You walk or ride a horse or use a buggy or a cart, as best suits conditions. You use field glasses less, as a rule, and a binocular level less. You use a hand level more, use the prismatic compass constantly, and have more need of pocket drafting instruments. In general, the field methods are the same, but closer attention to details is necessary.

It is well to make first a trip of fifty miles ahead unless a reconnaissance for route makes or shows this to be useless. After this trip, my own practice is to ride out from camp exactly on the line I believe I can get, noting aneroid heights, prismatic angles, and testing the average rate of slope of the long hills with the hand level. Keep careful notes of all this and of the drainage. Keep riding along on the line unless it is clearly too difficult, and continue for about fifteen miles from camp. Then turn to the right or left for a distance as far as one would be willing to divert the line in that country — say five miles. Then ride from this point of divergence straight back to camp. My horse would find this course. The next day ride out a little to that side of the direct line that promises the most improvement in line, and at the fifteen-mile distance turn squarely off in the other direction, and then return to camp. This plan works well in prairie country of usual difficulty, but not well defined controlling features. These distances were about the working limit of a good saddle horse. This gives fifteen miles in which to turn out for obstacles. It enables one to be sure where to run for six miles at least from camp—far enough for a good day's run.

In timbered country of the same difficulty the same plan is useful if one can ride through it. In rough country, the lines to be tried are more sharply defined and one needs to follow streams or divides and do less general exploring. One can ride a horse usually along one or two routes or close to them. For the rest, one must walk.

Having thoroughly looked over a piece of country and plotted your notes as you desire, lay out the line on paper in camp. Then ride or walk over this line next day. If necessary, modify the line on paper and put the sketches in shape so that the assistant who is with the line party can readily understand and follow the line. Finally, as you go over the line of this preliminary about to be run, mark that line on the ground. If there be fences a chalk mark or a piece of paper tacked up, or a strip of cloth fastened where the line is to cross the fence, shows the assistant that he has the line designed to be tried. In a wooded country a good mark is made by tying strips of white cloth to the bushes or branches while sitting on a horse. Where an angle is to be turned, mark the point on the sketch. The flags along tangents have no letter. Where the white flag shows against the sky line, or where snow is on the ground, make the flag of red and white strips. In a prairie country without brush or fences, any plan will suffice that does the work. I have picked out rocks, or stream heads or peculiar shaped saddles in ridges, showing them on the sketch. A paper pegged down on the side of a hole in a prairie dog dome is useful. Or, cut a sod or two with a spade and pile them upon level prairie. I have never found scantling necessary, though some have so found them.

To work close to the reading of the compass and put flags or other marks close together, and use a pencil to sketch the features on line is easier than using large signals. One can readily sketch and put field marks on a line so that his assistant can follow him day after day and carry his material for his field marks in his saddle pockets. One of the best devices for rolling prairie country, or indeed, for usual country anywhere, is sketching the *horizon*. It is a very safe plan and works well practically. By a *horizon* we mean a sketch showing just how the horizon appears to the eye of a man standing at a point D and looking ahead in the general direction of the route. Suppose you have gone carefully over all the country. You are at D and you know that you want to cross the next ridge ahead at a certain saddle some miles ahead and visible from D. You have marked down the angle to be turned at D, but you wish to confirm the new course and give the assistant a check on it. On your sketch and at one side, away from other notes, sketch the horizon ahead of you as it looks to your eye at D. Mark a cross on the horizon line exactly where the line should be turned from D for this divide. Mark this side sketch "horizon from D." If a tree or a rock shows just this side the horizon line and near the saddle to be reached, show this tree or rock on the sketch. In a word, you furnish the assistant each night with a sketch giving angles and distances and topography, and a record of sufficient, described field marks so that he can *readily* find the line to run without delaying the party to find out what you should have made clear. He should usually be able to do this without going ahead of the head chainman. The angles of the sketch are correct to within fifteen minutes. Closer than that the assistant uses his judgment. Odd minutes should seldom be used on preliminary. Line points need not be exactly passed over, but turning points must be picked out more closely than the distance from the last point that is given on the sketch. The flagging must be close on an angle point.

By this method no backing up should ever be necessary, and the assistant knows the night before where the line is ahead of him for next day. If it is found, in the judgment of the assistant, that the line seems to him not on the best ground, then he should show in his notes where that better ground is. If he finds an obstacle to line running, then offset for it and keep on the new route to the next angle.

The chief of party should do the finished reconnaissance work for line, but the assistant should have and use discretion. The party is not a machine. The assistant should be in line and in training, for a chief of a preliminary party. No *one* engineer ever worked a party right. He must have help and must use helpers right and teach them all he knows just as fast as he can. The company pays for the knowledge and judgment of each man on the party. The chief of the party should see that he hears and considers it all. To despise the opinions of assistants is dangerous. A man who gets the aid and hearty support of all the men under him is the safe man and the man whose average work is of the highest quality.

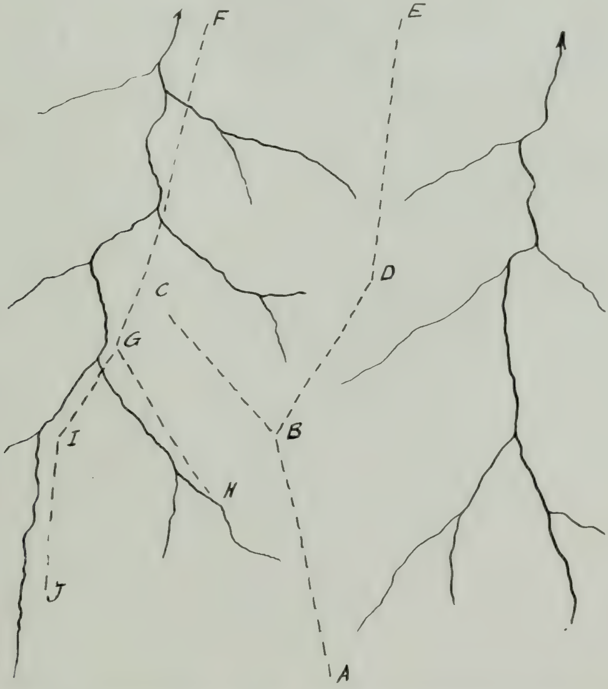
Railroad reconnaissance is the spirit of railroad location. It is based on good instrumental work by pocket instruments. It needs a trained eye for country, made so by practice with a level rod, use of level and transit, and practiced facility in topography. It requires good judgment. A man must be, and must keep, in good health or his eyes will deceive him and his value to his employer be impaired. It is fit work for the strongest vitality. It is never monotonous, for nature seldom repeats itself. It is work that is ever delightful to one adapted by nature to it.

DISCUSSION.

Mr. W. C. Armstrong—Mr. Beahan has given us a very complete and excellent description of what a systematic reconnaissance should be, and one which, if fully carried out in any particular case, would furnish all the data for a proper location. There is very little in the paper to which I could not give full assent. But as discussions are supposed to deal with matters of difference, I will refer to one point only wherein I differ.

Mr. Beahan states that on reconnaissance he likes to start at the top of a grade and work down; but would just as soon run a preliminary up hill as down; adding that usually locating engineers prefer to work from the top down. He apparently sees no other reason for preferring to work from the top down than that found in the human anatomy. His logic is evidently founded upon the theory of "least work."

My experience has taught me that in making a reconnaissance it is preferable to work up hill, if following a divide between watercourses, and down hill, if following a stream or watercouse. The reason for this is that one is less apt to be led into wrong situations and have to double back on his course. The point will be made more clear by reference to the figure. Suppose the engineer is following down the divide A B D E. Upon reaching B he will see a ridge extending to the left in the direction of C, as well as one to the right in the direction of D; and he may be led to follow the line from B to C before discovering his error. The liability to error is of course increased in timbered country where an extended view is impossible, and much valuable time may be lost. He is apt to make the same error if following up the stream F G I J. For upon arrival at G he may be unable to decide whether G H is the main stream or only a lateral branch. For these reasons I would say it is preferable to travel up a divide and down a watercourse.



In running a preliminary line, I think it makes little difference which way the line is run, except on maximum grade. In that case I would invariably work from the top down; and do not see how a proper development could be made in the opposite direction. I would like to ask Mr. Beahan how he would determine when to start his maximum grade if running up hill. Would he depend on the total rise being given by his aneroid with sufficient accuracy? And would he depend on some method even more crude for giving him his total distance? I am afraid his summit cut would often turn out to be an embankment, or he might find a tunnel necessary. But I may have misjudged the intention of his statements, and if I have I would like to be corrected.

The advantage of running a grade development down hill is not found alone in the fact that total rise and total distance are only fully determined when the grade has been run out, but the detail work of development is much facilitated. In running down hill the ground is lower ahead of you, and estimation of heights, distances, etc., are more readily made, because your level sweeps *over* the ground instead of *into* it.

In regard to the location line, it is usually immaterial in which direction it is run. If on the level or less than maximum grade, it is wholly immaterial. And if on maximum grade it may as well be run up hill as down if following a closely run preliminary. For if the preliminary has been closely run it determines the three principal desiderata, viz.: total rise, total distance and total curvature, and the location is merely fitting in the curves and tangents. On long stretches of maximum grade I think the preliminary line should be run with practically the same care as a location. Curves should be run in instead of angles turned; and the line should be closely fitted to the ground. The location is then simply retracing this line, carrying forward the stationing and levels consecutively.

This discussion may have gone outside of the scope of reconnaissance, which is supposed to be the subject under discussion, but if it has, I can only say that it was suggested by statements in the paper to which it refers.

Mr. Beahan I do not think Mr. Armstrong has gone at all outside the provisions of reconnaissance as to difference of opinion about running from the top or bottom of a hill. The custom I follow is: Suppose I get to the bottom of a hill which is going to require difficult work. I start at the bottom with hand levels, assume a height and run up that hill with a hand level. By this means I learn with sufficient accuracy the elevation to be overcome. I can then run the preliminary line *up* or *down* the hill fairly well. Knowing the elevation to be overcome and the rate of maximum gradient. I can develop that length on paper about as well from the bottom of the hill as from the top of the hill. Still, I prefer in difficult country to work *down* the hill.

Mr. Armstrong—This would not be practical on long stretches of maximum grade—for instance, grades from the summit of mountains where several miles are necessary for development.

Mr. Beahan—I have never used it for more than eight miles. Of course it takes a little time to run a hand level. On a long stretch of perhaps 25 miles it would not be practical, and you would have to start from the top. I see the point that Mr. Armstrong makes, and it is a very good one.

Mr. Geo. S. Rice I think it would be practically impossible, in a case of very high mountains, to follow the course of going up stream. My experience as a railroad engineer has been rather limited, but I recall that my first experience was where we had to descend a valley terminating in a cañon, and while the air line was only something like 8 miles, the development required something like 16 miles of maximum grade in winding in and out.

Mr. Beahan —When I get into a difficulty like that, of course I get the difference in elevation from the top and bottom by repeating aneroid readings, and then I make an assumption of the amount I think I can stand at the bottom or top, run a hand level down and flag it out. If the distance is long, instead of dropping my line I run up to the top.

Mr. Rice—I have used a barometer quite a good deal and have found that it is an instrument which requires a great deal of watching, as Mr. Beahan says, and I was interested in learning how it is possible to use a barometer in reconnaissance work. I would like to inquire in the case, where a second one is not kept in camp and where you do not go back over the same line, how you would manage it. My experience has been that the barometrical change during the day is very marked, and that it is not safe to take a reading in the morning and get back to the same point at night. In the course of the day there is often a change of 200 or 300 feet in elevation, and you may get very surprising results. I have only been able to get satisfactory results by repeating the readings, taking the time carefully, then platting the data on profile paper, and proportioning out for the result. I do not know how much this ground has been covered by others, and it is as a matter of information that I am making the inquiry.

Mr. Beahan—When I read the barometer during the day, I always make a note of the time I read it. The only way that I know of, where the variation is too much or not enough, is to throw away the readings and go over it again.

A Visitor —This paper is very interesting to me for the reason that I live in a very difficult country for this kind of work; a very rough country. While I have not been practicing engineering very long, I have had a great deal of experience, in different capacities, on preliminary surveys. One of the points that impressed me is the idea of some of the older engineers in making surveys of this character, making preliminaries by use of the transit. I remember one old engineer with whom I was on a survey, who run one curve over six times with the transit and could not come out at the right point. Finally he decided one line was pretty good and started work on it. He figured that he would come out at a certain point, and came out 700 or 800 feet west of where he had expected to come. He said that was pretty close to it and to go ahead. After we ran the line 6 or 8 miles we had to go back and run all over it again, and so we were, I think, 30 days in locating 10 miles.

Another point that impresses me is in regard to taking the advice of assistants. This old gentleman, referred to above, lost one of his transit men. One of the cross hairs got out of adjustment so slightly that he did not notice it, and at that time I was holding the rod and the rod was standing inside of plumb a little to one side. I tried to call his attention to it, but he paid no attention. After we got on 2 or 3 miles he discovered this, and had to go back over that again.

While these points are not of much value, I thought I would call attention to them; at the same time I think that assistants can always give some points.

Mr. A. S. Baldwin—Mr. Beahan refers to the subject of pacing distances. My experience has been that with care, quite accurate work can be accomplished on reconnaissance by pacing. I have always made it a point to check my steps frequently against distances which were known, or at least known approximately; by dividing the total distance by the total number of steps the average length of each step is given, and this can be used for the entire distance with quite accurate results.

I would like to know from Mr. Beahan if he has made a habit of comparing his reconnaissance with subsequent surveys, particularly so far as estimates are concerned, and if he has any figures to show just how these results would compare ordinarily.

One point made by Mr. Armstrong I do not concur with—that is, as to the desirability of extreme accuracy in running preliminary lines, particularly as to the features of running in curves on such lines. My experience has been that one would better use angle lines as a basis for topography, and then make a map location, rather than to waste time in unnecessary accuracy in preliminary work. I would like to have Mr. Beahan's experience on that point.

Mr. Beahan—With reference to the accuracy of pacing, my experience is that, counting—35 steps to 100 feet—I record them automatically as I go along. I step just about as accurate as the section lines show; I do not get out any more than that. I start from each section line over again, and so I do not let my error accumulate over a mile or a mile and a half; with a saddle horse it is more accurate. I used to record the distance to the even hundred feet—200, 400, etc. I allowed myself 100 feet each way, and the horse was accurate in that way of recording it. But I knew the rate of each of his gaits, and he never changed the gait. He was an unusual horse.

Mr. Warder—Is that measuring the distance by the element of time?

Mr. Beahan—Yes, the time at a known pace. My practice is, when we get where an angle is heavy or the country is difficult, to break the line for direction into several smaller angles, and not in one large angle. This keeps my tangent lengths more nearly correct when compared with the located length. In the case of difficult country we do not really use the full maximum gradient, but a less gradient to allow for compensating gradient for curvature. That is to say, if our maximum gradient be $\frac{1}{25}$ per cent and the climb is a crooked one, we estimate that on the average the maximum gradient on located line would be really $\frac{1}{15}$ per cent, and use that figure in reconnaissance. A man can guess at this equated rate of gradient very well when he has had practice. Or, on the other hand, on a crooked hill some of us attack the problem on reconnaissance from the other direction, and guess at the extra length of line needed between the ends of a maximum gradient to equate for curves. I understood from Mr. Hood, of the Southern Pacific Railway, that this was his practice.

Mr. Armstrong—The point I referred to was particularly in the development of long maximum grades. Ordinarily, on preliminaries, I simply turn angles where changes of direction are made, but on long grades of 10, 15 or 20 miles, as we sometimes have in a mountainous country, it is usually necessary to run the preliminary very close. I have very often, as Mr. Beahan says, run a series of short tangents, turning successive angles in one direction, but very often I find it just as convenient to run in the curves as I go. It is done for the purpose of getting the exact distance, so that the grade is properly developed.

Mr. Beahan—It seems to me it is quite necessary to bear in mind the distances in making a reconnaissance of any sort. Of course in such country where one is provided with a sectional map, it is possible to check up a possible distance.

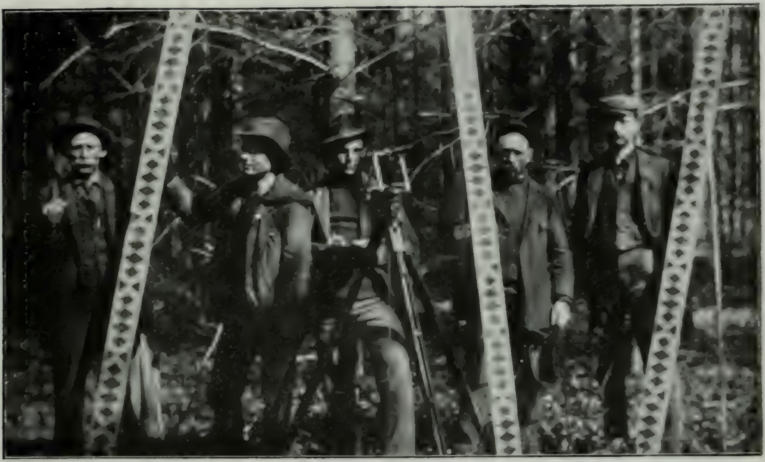
In the Dominion of Canada the land is not laid out in sections, as we have it in this country, and the maps are not designed for the use we would make of them in making a survey in the United States. Of course in a country that is quite rough and mountainous, and is heavily timbered, it is usually a great deal more difficult to get an idea and to judge the distances. By means of the barometer and other instruments it is usually possible to get the difference in elevation with greater accuracy than it is without these instruments. In timbered country the difficulties in getting through the brush are so often so large that it is almost impossible to count your paces, and the obstacles are often of such character as to cause you to lose altogether the idea of the distance you may have had when you started out. I think a good deal can be said on the different ways of measuring horizontal distance and getting it.

Mr. H. S. Maddock—One point has impressed me; that is, in timbered country I think engineers as a rule waste a good deal of time cutting timber on preliminary surveys. I have found it possible to make use of the bridle paths, run a transit line and work the same as the mining engineer does; then connect my diagonals in the direction I want to go. The country can be examined with the compass at the right and left of the bridle paths, and in this way save a good deal of time in chopping. On one location there were two parties in the field, and by adopting that method I saved a week's time and secured a shorter line than the other party.

Mr. Torrance—In regard to that feature of running in curves in order to determine the maximum gradients—I should not think that that would be necessary, if that was the only reason, because it would be a very simple calculation to determine from the angle in the line, and the maximum or desired degree of curvature that was going to be used, what the length of the finished line would be in any case, and the survey work would be much easier, especially in timbered country.

Mr. Beahan—That is true, but the profile would not show right.

Mr. Torrance—I meant to cover that by saying, "if that was the only reason." Of course if the country varies cross-wise a good deal, it would require that the broken line be run.



A Stadia Party in the Field.

CLXXXII

TOPOGRAPHICAL SURVEYING.

By W. C. Bunnel, Jun. M. W. S. E.

Presented June 3rd, 1903.

The stadia method of surveying was officially adopted by the United States Engineer Department about 1864, but outside of this department until recently it has been used very little, although engineering books tell us that it has been known for about eighty years. The reason for this seems to be that work undertaken by the general government is preceded by an exhaustive research, as there must be no mistake caused by lack of data. This as a rule requires that large areas be surveyed with a great amount of detail, so the above method is used. But in any case the whole argument may be reduced to this, basing it on the fact that detail is required: Given an extensive area including swamps, streams, timber, etc., how can all the intervening detail be best obtained? With the stadia by one pointing of the telescope elevation, distance and position are obtained, otherwise requiring pointing of telescope, chaining and leveling. Without discussing further its adaptability, the following notes are given, not as how it should be done, but what has been done and some results obtained:

CARRYING AZIMUTH.

Of course care should be used in all the different operations, but probably the angle readings on an instrument should receive a second look if any do. All work should be referred to a true meridian.

as it makes it intelligible and simpler and is just as easy and rapid to carry out—by this is meant that each point is located by an angle to the true meridian as follows: In starting the work the azimuth of one line is known from a previous observation; now by setting up at one end of this line and setting Ver. A to read the observed azimuth when pointing along the line (or by adding 180 degrees if back-sighting) we can by clamping the lower motion and turning with the upper refer all reading to the true meridian by noting the reading of Ver. A. Every angle thus read then has a clear definite meaning—for instance, if the zero is taken as north and is so placed, then a reading of 90 degrees shows that the object sighted at is directly east of the instrument.

Errors in this part of the work are quite easily made and some precautions should be used. One way is to repeat the angle between the consecutive courses, say four times, and take the mean of these which by means of the azimuth of the last course gives the azimuth of the next.

Another and quicker way is having set Ver. A on the back azimuth of the last course and back-sighting along it, then loosen the upper motion and read to the forward station; then set back on the last station and read, observing if it is the same as the back azimuth—again point to the next station and read, seeing if it agrees with the first reading ahead. These last two readings check the first two. By calling these readings to the recorder a check is also obtained whether he gave the back azimuth correctly to the observer. A simple precaution with the above is on first setting up at each station, measure the angle once or twice between the courses and keep a record of it—ten minutes a day spent in doing this will later save a great amount of time and worry and show at once just at what point the error was made, if there be one.

ELEVATION.

With the present perfection in transits little need to be feared as to accuracy of azimuth, distance or elevation. By reading both forward and back over each course sufficient accuracy for topographical work can be secured. The average of several stadia lines amounting in all to 12.72 miles gave an average error of .108 feet per mile.

DISTANCE.

The operation of the stadia depends on the well-known principle of the similarity of triangles, the visual angle subtending a certain portion of the rod at a given distance, this subtended portion increasing as the distance increases. But the system of lenses used in a transit prevents the direct use of this proportion as the distances are really measured from a point in front of the object glass equal in distance to the focal length of that lens. As the distance from point to point (center of instrument to next point) is desired, a correction must be applied. This fact is sometimes used as an argument against stadia measurements but text-books on surveying give ample means for correcting this. As to whether it is worth while to apply corrections the writer would say that out of 282 courses the corrected stadia readings were in error 1:1987 as compared to chain measurements while the uncorrected readings showed a much larger error.

The fact that a stadia circuit closes up on the starting point with a very small amount of error is no criterion by which to judge of its accuracy, because in returning to the starting point we must have gone as far in one direction as another, the errors balancing one another. The test of accuracy is by starting on a base line at some point and close on another point. From several stadia lines thus run the average error was 1:1748. In running 59.6 miles of line in which there was 282 courses the shortest being 189 feet and the longest 2,565 feet, the average being 1,113.7 feet the error of the stadia readings as compared with the chain distances was 1:1987. There were 147 courses 1,000 feet or over, which made up 42.4 miles of the above and by summing the corrected stadia readings and chain measurements respectively for these courses the stadia differed from the chain by only 28.3 feet; any further comment on such an actual result is left for others.

According to the theory of probabilities just as many points will be located at even distances from the instrument as odd distances, but practice shows that this is far from being the case. Various causes are assigned for it and some time ago in the Proceedings of the Engineers Club of St. Louis it was stated that it was the fault of the graduations on the rods as the even readings are indicated by points or lines of the graduations and are therefore used much more than the rest of the graduation, which has to be estimated, and a type of graduation was suggested to overcome this tendency, but as all figures are limited by lines any form will have the above defects.

After careful study of the work of different observers, together with data from others, it does not seem to be due to any form of graduation and the conclusion reached is that it is a matter of personal equation for the following reasons: To carry on a survey economically the observer should know for what purpose it is required, the accuracy desired and the scale to which it is to be plotted. Now as a rule, the scale to which topographical maps are drawn does not admit of any such refinement of reading side shots to the nearest foot and usually the object of the survey does not require it, so knowing this, the observer in order to save time, will read some even mark rather than estimate the odd number of feet, especially when the reading wire is near some such division as 10, 20, 30, 40 etc., this being done not on account of any form of graduation or inability to estimate, but simply by the will of the observer. Again he knows that in plotting, odd distances will have to be estimated again and also in reducing differences of elevation from a chart. Another proof that the above is a personal matter is shown in reading the courses which make up the stadia circuits; here the observer is aware that odd distances can and will be used in the calculations of the courses and an examination of these readings gives a more equal percentage of odd and even readings as shown below. Another fact is the reading of vertical angles; here he knows that single minutes can be used in obtaining difference of elevation and that they will be used whatever may be the scale of the map, the percentage of odd and even readings being about equal in this case.

In order to show how the number of odd and even readings run the following examination was made of note books of a recent survey:

Observer	No. of Shots	Odd	Even	Per Cent Odd	Per Cent Even
A	10862	3428	7434	31.5	68.5
B	6946	2257	4689	32.5	67.5
C	8655	2762	5893	31.9	68.1
Summing	26463	8447	18016	31.9	68.1

But in reading distances between stations (with same rods as for side shots) the following may be noted:

Observer	No. of Courses	Odd	Even	Per Cent Odd	Per Cent Even
A	509	214	295	42.0	58.0
B	562	230	332	40.9	59.1
Summing	1071	444	627	41.5	58.5

The above shows a higher percentage of estimated distances than for side shots.

SKETCHING.

Much has been said both for and against field sketching. All will probably agree that the case is yet to be found where notes have been too clear and no doubt all instrument men recall the familiar command to make the notes so that anyone may understand them. Now why is a map made? All the information to be gained from it is in the note book, such as elevations, relative distances, etc. A map is a sort of a reduction from nature, showing things as we see them on the ground. Just so with the sketch; it conveys more to the mind of just how things are than the most elaborate system of written descriptions.

In constructing a map we simply sketch in objects certain distances apart, so that if we have something showing the relative position of objects and notes stating the distances and elevations all else should be plain. Inaccuracy in sketching cannot show in accurate plotting, so a sketch need not be an accurate piece of work.

Take for instance, the outline of a swamp where all the elevations are about equal, and after plotting the points a great many lines may be drawn through them, defining its boundary; yet there is only one correct line and it is the duty of the sketch to show which it is. The sketch should be made in the field and be as clear and full as possible. There are many ways of doing this, but the following makes as clear and correct a sketch as could be desired. Having selected a point on the page of the note book to represent the station being occupied, draw a small protractor around it; this is easily done by having a small paper circle about two inches in diameter, with the five-degree points marked on it, and laying it on the page and making a dot at each division point; with a small scale about five inches long and suitably divided, all sights can be at once plotted on the sketch.

This method has many advantages. It detects errors both in azimuth and distance which otherwise would pass unnoticed until the final plotting. It shows just what ground the rodmen are covering and how they are doing it; in fact it gives an excellent idea of just how the map will show up when plotted and also something that can be relied upon at all times. It may be said once for all that this method is more rapid than free-hand work as there is no studying just how things should be located. It takes no extra time to do it; after recording the reading given by the observer and while he is making the next pointing the recorder plots the last reading. The engraving represents a note book with a field sketch, made as described above. Each "shot" or sight is indicated by a number which corresponds to the number in the notes. Sketching in the note books has the advantage of always being with the notes and doing away with a lot of loose sheets on which no more information could be given.

NOTES.

In beginning the notes for each day, the names and positions of each of the party should be given, together with the date and locality of the work. In fact, the date and station occupied should be on every page. The sights should be numbered from 1 continuously for each day's work, and then there can be no confusion in the sketch, and should begin at the bottom of the page. A short description of each sight will be found of immense value, such as "water surface," "edge of timber," etc.

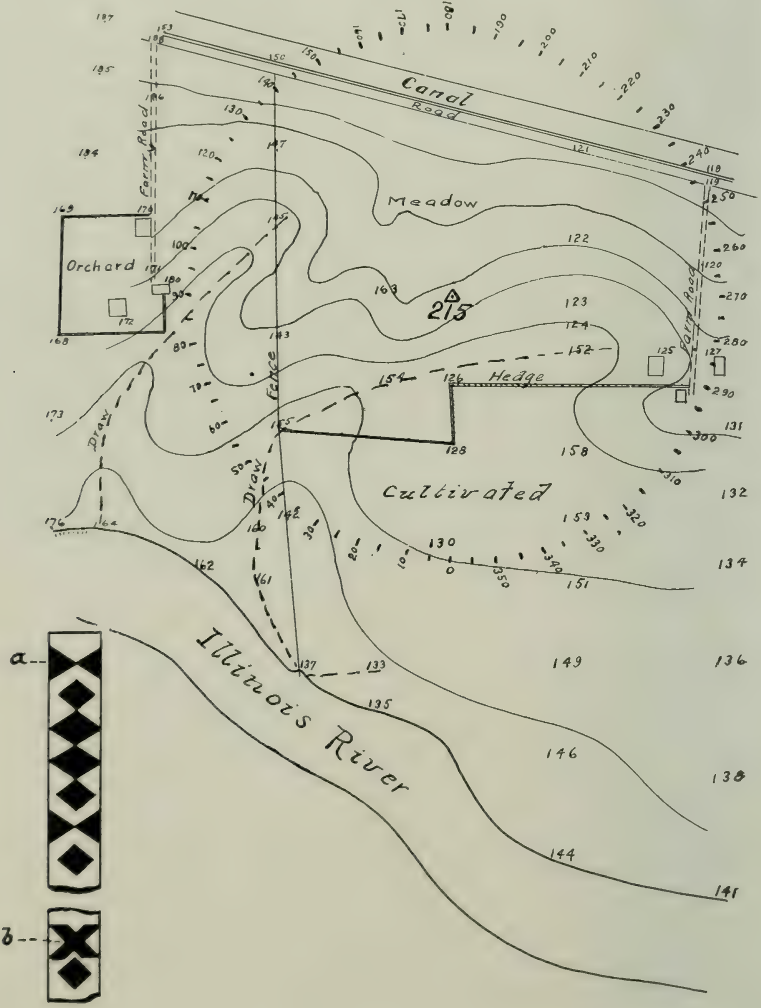
The recorder should repeat back to the observer the readings as he receives them, thus avoiding any misunderstanding.

There is no logical reason why all notes should not be perfectly clear to anyone having occasion to use them, yet it is a fact that it is the vagueness of notes rather than their inaccuracy that gives the draftsman trouble.

Let everything proceed in order, but if necessary to change to a different part of the note book, make a note of the fact, referring to the page on which the notes are continued. Care and detail are two absolutely essential elements for clear notes; carelessness is fatal.

RODSMEN.

The recorder for a stadia party should be able to handle an instrument well and to take charge of the work in the absence of the



observer; then for a few days a great amount of good can be done by the observer going over the ground with the rodsmen and showing them just how he wishes their part done. This of course applies to extensive surveys and new rodsmen.

Each rodsman should have a distinct signal so that there will be no confusion when all are some distance from the instrument. Then again it will facilitate the work if a system of signals be arranged so that the observer may know just what he is taking. At first thought this last suggestion may appear unnecessary, but experience has shown that all soon learn and like it, and all that screaming, which is so irritating to both observer and rodsmen, is entirely done away with.

It should be the duty of one rodsman to always give the backsights and another to put in the station ahead. The head rodsman should be the most reliable and experienced man as the rapidity of the work will, in a great measure, depend on his action and judgment.

Shots should not be taken promiscuously, but should be given with some system. A good plan is for the rodsmen to cross-section the ground by following out a line to a certain limit and then returning on another; of course the object of the survey and the nature of the ground will determine just how close these shots should be taken. This will not only make a better appearing map but makes it a much simpler matter to draw in the contours rightly. They should be careful to get all the critical points, i. e., the breaks in the slope or changes that determine the contours.

RODS.

Good rods are essential for good work. They should be made of the best smooth straight grained white pine, thoroughly seasoned and at least four inches wide and three-fourths inch thick and between twelve and fourteen feet long. If the first two conditions are not fulfilled the boards will warp and the paint crack and come off, thus presenting a very rough appearance and make the readings more difficult. The surface should be perfectly white, with black symbols. They should be graduated in the simplest manner possible because, as Professor Baker says, when far away the small divisions cannot be seen and when close an error is liable to be made in counting them. The graduations should be started about 0.5 foot from the end because usage in mud, etc., will wear away the lower marks. The main object is to get a perfectly distinct, sharp outline to the symbols, as experience has shown that there should be a sharp point or edge on which to set the wire to obtain an accurate reading; i. e., a better reading is secured by having some such symbol as shown at *a* in the figure than that indicated by *b*.

The greatest care should be exercised by all to avoid errors and misrepresentation in the field, as such mistakes are fatal.

A judicious and systematic selection of points, a full description of them in the notes, good sketches and bearing in mind the object of the survey, are essential elements to reliable and economical results of a stadia survey.

DISCUSSION.

Mr. E. T. Eriksen, M. W. S. E. (by letter)—Mr. Bunnel's paper has been very interesting to me. Having had several years' experience in this work, it seems to me that for topographical work and generally for any kind of mapping, the stadia method, with some modification to suit the degree of accuracy required, is far superior to any other, both for rapidity and accuracy in field and office work.

To any one familiar with the method, its adaptability to any kind of mapping is very plain. The objection usually made by engineers not familiar with the work is that it is inaccurate. This objection may be both right and wrong. The stadia method is not accurate enough for many purposes if not correctly and carefully applied, but with careful, intelligent work and a few modifications—if you please to call them such—viz.: the use of the steel tape on important lines and the wye level in carrying elevations over important points, notes may be taken as accurately as by any method and more accurately than they can be plotted in ordinary map work.

The surveys where the stadia method is useful vary from those for small scale maps with little detail and a large contour interval, to those for maps in city territory to a scale of 50 feet or even 10 feet or less to the inch for small areas, with buildings, railway tracks, walls, dock lines, etc., to be located.

In extensive surveys, a system of triangulation usually forms the skeleton of the survey and the details of topography are filled in by stadia. The triangulation lines form good checks for stadia circuits which may be computed and balanced before plotting. When the elevations of triangulation stations or a line of precise B. M^s. are also known, the elevations carried by vertical angles can also be checked and the stadia survey can generally be made without future use of steel tape or level.

When the triangulation system is not warranted by the extent or importance of the survey, circuits should be run with angles repeated, and lines carefully measured with steel tape. Latitudes and departures of points in the circuit should be computed and the circuit balanced before platting. The error of closure should be well within the limit of accuracy required.

For filling in details for large scale maps the tape should be much used and wye levels run over all stadia hubs. An inexperienced observer often seems to think that, because he is making a stadia survey every distance must be read on the stadia rod and a vertical angle recorded. On the contrary, all points within 100 feet of the stadia station occupied are much more quickly and easily located by measuring distance with tape, and vertical angles need be taken only in sufficient number that contours may be easily drawn. This applies to work in cities and around railway yards, etc., where there are many points to be located in the map.

The stadia stations here may be made close enough together, say 200 to 300 feet apart if necessary, so that all important points can be located by tape measurement, the azimuth of course being taken as usual. A good metallic tape is usually accurate enough for side shots, and with two tapemen their work goes on rapidly. For taking the vertical angle, if one be required, to a point measured in by tape, there should be a small rod about 5½ feet long on which a simple form of target is placed. The target is set at the elevation of the height of the instrument or H. I., and the vertical angle taken by setting middle hair on the target as the rod is held by the tapemen. Lacking the target a card may be tacked to the rod. This rod or stick, if graduated to feet and tenths to correspond with lower end of stadia rods, is very useful in getting the H. I. at each station.

The recorder soon learns its usefulness for this purpose and also as a weapon of defense when passing premises where the dog is not kept tied, so that he is readily induced to carry it along on the work and generally prefers one made of hardwood. Readings by stadia rod are still taken at points not requiring accurate location or to obtain elevations for contouring. All buildings and other structures to be located should be measured with the tape and placed with their dimensions on the sketch.

By following this method an accurate map may be obtained. The advantages of this method over the old way of using base lines and right angle measurements for mapping and then cross-sectioning with level for elevations, are the perfect uniformity and clearness possible both in taking and platting notes, the completeness of detail possible, and the rapidity with accuracy. The work can be done with three men all told, but better with four and the party should consist of at least five men for all extensive surveys. On railway location or preliminary survey, where the center line is run and stakes set, it would seem to be a comparatively simple matter to take stadia readings along each side of the line from stakes say every 2,000 feet. Certain it is that more accurate topography could be easily taken than by the usual method. A discussion as to the comparative cost and results would be interesting as compared to the usual method in railway location. As far as the writer knows the stadia has not been used on railway topography.

As stated by Mr. Bunnel considerable care to detect or prevent errors in carrying azimuth is necessary for successful work. One good way to detect such errors, where there is no magnetic disturbance, is to take the needle reading on each course between stadia stations, also on shots to important points, such as section corners. Nearly all transits are furnished with the magnetic needle and a comparison with the needle readings serves to detect any large error in azimuth. The true meridian should be found on starting the survey, usually by an observation of Polaris, and if the survey covers much territory, new observations for meridian should be made from time to time and the azimuth corrected, both for convergence of meridians and any cumulative error in running.

As to the correction to stadia readings for focal distance, it has been the writer's experience that an observer readily learns to add the correction (usually 1 foot even, in ordinary shots) when taking the reading, and seldom fails to do it, thus making it unnecessary to correct the notes after they are recorded.

As to the sketching, the writer agrees with Mr. Bunnel that the sketch is a very important part of the field notes. More information can be conveyed, and more clearly, in a few moments by a sketch, than can be obtained by a long study of descriptive notes.

The writer would disagree however as the method of making the sketch. The sketch described is simply a rough plot of the notes and any errors by an observer in distance or azimuth, or by the recorder in taking down same, are copied onto the sketch. The writer remembers at one time making a sketch by this method and being complimented by his superior for making a true sketch that "looked just like the map." In fact it could not look otherwise, and no skill at all in sketching was required.

The map is a representation of the territory transferred to the paper *through the notes*:—while the sketch should be a rough map of the same territory transferred directly by observation to the paper—and being independent of the notes, serves as a check on errors of location by the notes. Instead of seeing "just how the *map* will show up when plotted," it should be the first business of the field party to make sure just how the ground looks and represent it in the sketch. Of course, if the sketch is all made by this method in the field, as the author recommends, errors in the notes may be noticed and corrected, and such a rough plot is often useful to detect errors in azimuth and distance.

It would seem, however, that the work described by the author in reference to the sketching, must be that of a slow observer. It is the writer's experience that an observer with some training, having three rodmen, in ordinary country, can keep a recorder exceedingly busy recording stadia notes, in fact can sometimes take readings faster than they can be recorded, to say nothing of plotting them on the sketch. Also at any one station, several pages of notes are usually taken and the recorder must either turn back to the sketch or copy it on each page used at that station. The result is that either the work is delayed to allow the recorder to make the sketch, or, as is much more likely, he makes his sketch at some leisure time, probably in the evening after work, where he cannot see the ground covered, consequently the sketch is less reliable as a true picture and as a check on the notes.

In the writer's opinion, it is a good plan for the head of the party, when there is one other than the observer, to sketch the territory ahead of the stadia work. While doing this he decides where and how he wants the shots taken and afterwards instructs the rodmen, and also instructs the observer how to advance with his work.

The sketch in this case should be made in a separate book or on sheets of cross-section paper on a small drawing board, some smaller sketches for reference hubs, etc., may still be kept in the regular note book. The sketch book, or the sheets, carefully marked and mounted if necessary, are sent in to the draughtsman with the note book. Where the observer is also the head of the party, he should look over the ground ahead of the work and make the sketch while the recorder is left in charge of the instrument. In this case the sketch may be made in the regular note book. This is always advisable when possible without delaying the whole party. It may sometimes be more convenient to make the sketch after the notes have been taken or to have the recorder make the sketch. A carefully run circuit may be used as a skeleton, but details should be without reference to the notes. On extensive surveys it is good practice to have a draughsman with the party who plots the map as the work proceeds.

Rods, as described by Mr. Bunnel, graduated with large, plain figures, the smallest division being $\frac{5}{100}$ of a foot have been found most satisfactory in the writer's experience. It is a great convenience in taking the vertical angle to have the 4-foot mark from the bottom of rod, painted red or otherwise distinguished from the other foot marks.

One important requirement in rods for good stadia reading is to have them graduated to fit the instrument to be used, since the makers are seldom able to place the stadia hairs so as to subtend, with exactness, 1 vertical for a horizontal distance of 100 (focal distance allowed).

Graduating the rods requires considerable care. In the writer's opinion, the most favorable conditions of atmosphere should be selected for doing it, as on a "clear cloudy" day, when errors due to refraction and unsteadiness are reduced to a minimum.

Mr. W. M. Torrance, M. W. S. E.—Mr. Bunnel states that he is not aware that stadia had ever been much used in railroad work. I would like to state one little experience I had while with the C., C., C. & St. L. Ry. The case was one in which it was desired to build a cutoff for freight trains south of the city of Anderson, Ind., the main line being approximately a semi-circle of about 1 degree curves through the city, and the cutoff to be practically an east and west line on the diameter of this semi-circle. With only one rodman I made a preliminary survey sufficient to plat the necessary topography, (the notes for which were entirely by stadia distance and horizontal angle) and a profile for this line, my preliminary line as run being always toward a foresight, which I would never quite reach before turning an angle to another foresight, thus not requiring any rear flag. I did this work entirely with a transit which carried a level bubble and stadia wires. I took the profile at each station by spotting my rodman by means of the stadia, and when he had advanced five or six hundred feet from the instrument I would spot him within a foot of the correct distance by means of the stadia and he would hold this point until I advanced. I would then get my new height of instrument by measuring from the ground up to the telescope with the rod. Thus, without the use of a tape or chain, and with only one man, I was able in two days by the help of the stadia to accomplish preliminary line work which would have taken much longer and required much more of a party if done in the ordinary manner, and as we had an accurate profile over the existing main track line I had means of determining how accurately the work would turn out to be, and in this it was remarkably close.

What occurred to me at the time, and what has occurred to me many times since, is that some such method could be used very often, especially in comparatively level country, for much longer preliminary line work.

Mr. A. C. Schrader, M. W. S. E.—The statements made in Mr. Bunnel's paper on topographical surveying, evidence field experience and good methods of doing the work. The suggestions contained in his paper are important and as a rule govern the operations of experienced observers. It is hardly to be expected that the entire subject of topographical surveying can be covered in a condensed paper on this subject, but the essential points may be stated, leaving the detail to the ingenuity of the observer, who, however, must know the degree of accuracy and the completeness of survey required to enable him to determine the detail methods.

The following methods have been used by myself, when complete detail is required for an extended survey: The ground is first covered by a series of circuits and the principal stadia stations are located upon these circuits. The distances between the stations are accurately measured with steel tape and the azimuth of all lines determined by a proper measurement of all angles, even repeating the angle readings two or three times for accuracy. From these notes horizontal co-ordinates for all stadia stations are computed and platted to the desired scale. Wye level elevations of all stadia stations are also taken and closed in circuits. With this skeleton survey as a basis, we can now proceed to develop all topographical features in detail and can rest assured that no greater error can occur in the field work than that of a single side shot, and for this we must in all cases rely on the accuracy of the observer. Some of these side shots will be in error, (perhaps ½ of 1 per cent of the number) but they are readily detected by the observer if he scans the field plat and may usually be discarded with safety if sufficient points are taken, or else corrected.

The accuracy of reading distance by the stadia as stated by Mr. Bunnel, that is, 1 foot in 1,987 feet, seems to me to be very good as an average. From this, however, I do not understand that every distance read will fall within this limit. This limit of accuracy is considerably affected by atmospheric conditions, which in turn is affected by ground conditions over which the sight line lies. One can frequently notice on a hot day a very *active* set of graduations on a stadia board, when the sight line lies along the railroad track and it is not an easy matter to read such a distance under similar conditions.

The work of the observer is continuous and certainly cannot be considered a rest cure if he can take 600 shots daily. This means, that with 600 pointings recorded, 1,200 angles and 600 distances are read. Speed of observation, however, should at all times be secondary to accuracy, and a beginner can seldom be trusted to make safe observations for more than one or two hours per day, and it is well to check him often even during that hour or two.

In territory where numerous *improvements* are to be shown, sketches are essential for complete detail and the locations of such prominent objects as bridges, buildings, etc., should be fully supplemented by detail sketches and measurements and in city work a separate sketch book may be kept advantageously for this purpose. For open country work, the sketches are not so essential, but are a distinct advantage if the recorder can properly place the same in the observer's book. The observer's notes, however, should be so complete as to leave no doubt as to all important topographical features and the proper co-ordination of points located.

As to the general applicability of this method of survey, even when the notes are platted to as large a scale as 50 feet to the inch, there is no doubt in my mind. The versatility of the method, and the ease of accomplishment with the completeness of detail, commend themselves to all who have understandingly given it a trial. You can make a most excellent paper location of a railway over ground covered by a good stadia survey. This is particularly applicable in ground which may require a number of trial lines for railway location, as over broken country, and the map is a distinct asset in after years.

This method of survey is also particularly applicable in making a complete survey and map of parks in which numerous curved drives, walks, wooded areas, lakes, buildings and bridges are to be definitely co-ordinated, as well as all sewers, manholes, catch basins, lawn hydryants, water mains, electric conduits, lamp posts, in fact everything pertaining to a *complete* map, and this means much to all who have who have to use and refer to such maps and to rely upon their accuracy.

CLXXXIII

TIMBER TREATING PLANTS.

W. W. Curtis, M. W. S. E.

Read May 20, 1903.

Changes in this country come quickly at times—five years ago when the writer began to write on the question of the treatment of railroad ties, the interest in the question was largely academic. Many recognized that the subject was one that would require consideration in the future. The day when it would become a live one, was apparently as far off as ever. For fifty years, something in this line, has been done at intervals. There has been occasional flurries, when for a time, there would be general interest in the subject. Some far seeing man would recognize the fact that even our forests had a limit, and here and there attempts were made to begin the use of treated timber. Prophecies have been made that ten or fifteen years would see the practical end of our resources; but before that period had rolled around, fresh forests had become accessible and with better methods of merchandising and cheaper rates of transportation, the required supplies continued to be furnished at the same rates. Plants started to treat ties, either because of poor locations, mistaken treatments, or from changes in management were abandoned. Timber treatment must necessarily be expensive in first cost and with slight difference in price of first quality timber and that of an inferior grade, suitable for preservative processes, the treated tie cost as much or more than the untreated, and even with the prospect of an extended life for the treated tie, the first investment was too much for the managements interested in a good financial showing for the moment, to consider favorably. In fairness, too, one must admit that the results of experience in the use of such ties in the past, was in some doubt. The records of such experience were in a very unsatisfactory condition. Ties had been put into service, watched for a few years, and then lost sight of. The actual results were unknown or disputed. In 1885 a committee of the American Society of Civil Engineers, of which our fellow member, Mr. Chanute, was chairman, made a most valuable report—but the years following were unpropitious, and in the year 1899 but three roads in this country were making any large use of treated timber. The writer estimated that during the twelve years preceding 1899, 10,000,000 ties had been treated.

Today, conditions are different. There are now sixteen works in operation furnishing ties to fifteen, or more, railroads. Probably more ties will be treated in the twelve months of 1903 than during the twelve years preceding 1890. This is due to the more general satisfaction that treatment is effective, and the inability to secure a sufficient supply of first-class untreated ties at any price. The situation in a few words is this—our railroads must have ties; they are unable to secure such ties as they have formerly used, to fill their requirements; they know inferior ties will give but very short life; they believe such ties treated will last longer; and they can purchase them at a price that, with the cost of treatment added, will not exceed the cost of the first-class untreated tie.

This is is the least favorable presentation of the case of tie treatment, but it is a conservative one, and in some portions of the country where the climatic conditions are not favorable, perhaps all it is wise to say regarding timber treated by the cheaper processes. In dry climates, much more can be promised safely. With the experience of the A., T. & S. F. Ry. extending over 17 years, showing an average life for the treated inferior pines and spruces of 11 years; and the same number of years' experience of the Atlantic System of the S. P. R. R. of 9½ years and the shorter experience of the Pacific System of the same road, showing 75 per cent of the ties laid in 1895 still in service June, 1902, after 7 years in the track, it is possible to predict a life for treated ties impossible to duplicate with white oak, under the same conditions. It is certainly safe to say that a tie properly treated by the usual zinc chloride methods, will last as long as white oak.

While it is not the writer's intention to here go over ground which he has attempted to cover elsewhere, it may be well to refer briefly to the various methods of treatment now in general use.

First of all because of its age, cheapness, and general use, is that of burnettizing or the injection of zinc chloride alone. This has been used by the S. P. R. R. with the results already stated. The objection to it is that as the preservative used has a strong affinity for water, it is dissolved out of the timber in time and when the amount of the salt remaining becomes less than a certain minimum, fungus life can begin its work of destruction. The dryer the climate in which the tie is exposed, the longer the time in which the salt will remain in the wood, in sufficient quantity to preserve it. Presumably also the greater the quantity injected, the longer it will take to leach out the salt. To get good results from burnettized ties, it is especially desirable that they be thoroughly dried after treatment and placed in a well drained roadbed. These are essential conditions for the best results from any kind of treatment; but particularly so with one where the preservative is as soluble as zinc chloride. If the tie has been well dried out after treatment, its cells will be filled with air and then when placed in a well drained track, the rain which falls upon it will first have to displace the air from the cells before it can find access to the tie; resulting in but small penetration before the storm will have passed and the water drained off. On the other hand, with a tie laid in a poorly drained track, and while still full of the water of treatment, there will immediately begin the transference of the salt within its cells, to the water without, continuing until the quantities balance with no salt in either.

Next to burnettizing, is the Wellhouse, or zinc-tannin treatment, begun some 25 years ago, and still in use by Mr. Chanute. This is an attempt to remedy the difficulty of the solubility of the zinc chloride, by the addition of other materials intended to seal up the ducts of the timber. This is done by means of the injections of glue and then of tannin, following the chloride, the glue and tannin forming an insoluble compound. There have been several processes brought forward intended to perform this same function, some of them would appear to have more promise in them, than the Wellhouse; but it alone remains in use today. Whether the others failed to do what was expected or were unfortunate in not having had correct records kept of them, may be a question. Certainly, the ties treated by the zinc tannin process have given satisfactory results, where any record was kept. Of late it has fallen somewhat into disrepute because of a doubt as to the additional life secured by the glue and tannin being equivalent to the additional cost of treatment. There should be sufficient records to demonstrate the relative values of the two processes, but if there are such, the writer has been unable to discover them. While he is not an enthusiast on the subject, he believes it the part of conservatism to continue the use of the glue and tannin until we have some evidence that the zinc alone will give as good results. The additional cost is only about three cents per tie; and as each year's life is estimated at five cents, it requires but a small increase to warrant the additional expense. The test now under way in Texas under government auspices may soon determine this and other questions.

Next are the zinc creosote treatments, consisting of the injection of the chloride of zinc and creosote oil, either together or separately. Creosote being the best timber preservative known, any process using it would naturally be expected to be an improvement over others. To use it alone requires so large an amount to get a distribution sufficient to have any value, as to be generally prohibitive for ties in this country on the score of expense. A tie properly creosoted would absorb too much even if only soaked in it, while the penetration under such circumstances would be but superficial. The endeavor has consequently been to devise some method of using it in combination and two such are now in greater or less use. One, used largely abroad, consists in mixing a very light oil with the solution of zinc chloride and injecting them simultaneously into the timber, using about 1¼ pounds of creosote, and ½ pound dry chloride of zinc per cubic foot of timber. The other, used to a small extent in this country consists in the injection of a solution of zinc chloride first, to be followed by an injection of creosote oil to the extent of about 4 pounds of oil per cubic foot. In the first, a very light oil is necessary to insure the mixing with the water solution of the zinc chloride. In the second, a standard heavy oil is used, and in large quantity. The method of using the oil and zinc chloride in one solution, has been used experimentally, in this country; as well as a modification, increasing the quantity of the oil to 4 pounds per cubic foot and using the usual grade of heavy oil, instead of the light oil required by the German specifications. This zinc treatment promises to be of great value, undoubtedly being superior to the other processes, thus far described, and much cheaper than regular creosoting. The German method of treatment is the cheaper, using less oil and requiring but one injection instead of two. The particular kind of oil required, however, is difficult to obtain in this country, and the treatment does not appeal as strongly to the writer as does the method followed in this country. The province of the oil is mainly to prevent the leaching out of the metallic salt and when the oil is of a heavy character and deposited principally near the surface of the tie, it will certainly perform this duty better than if it be a light oil and is distributed through the timber. Nothing but experience can determine the facts, however. The German method has given good results abroad and the American method has done well here so far as it has been tested.

The most perfect method of timber preservation is unquestionably by straight creosoting, or the injection of an amount of good oil of coal tar, depending upon the exposure of the timber. This amount will vary from 12 pounds per cubic foot for ties, to 24 pounds for timber or piling subjected to the attack of the teredo in tropical countries. The only objection to the use of creosote, is the cost. The oil is worth about 1 cent per pound, making it cost for a 6 x 8-inch tie, 32 cents for the oil alone, on the basis of a 12-pound treatment. When our roads are prepared to pay the cost of creosoting their ties, they can expect a life from them of about 20 years, provided they do not cut out before they decay.

There is only one other treatment worth consideration at present and that is by what is known as the Hasselmann process. This consists of boiling the timber in a solution of several substances, the principal being the sulphate of iron. There are some very attractive features about this treatment and it is quite possible it may be the desired treatment which shall be efficient and cheap.

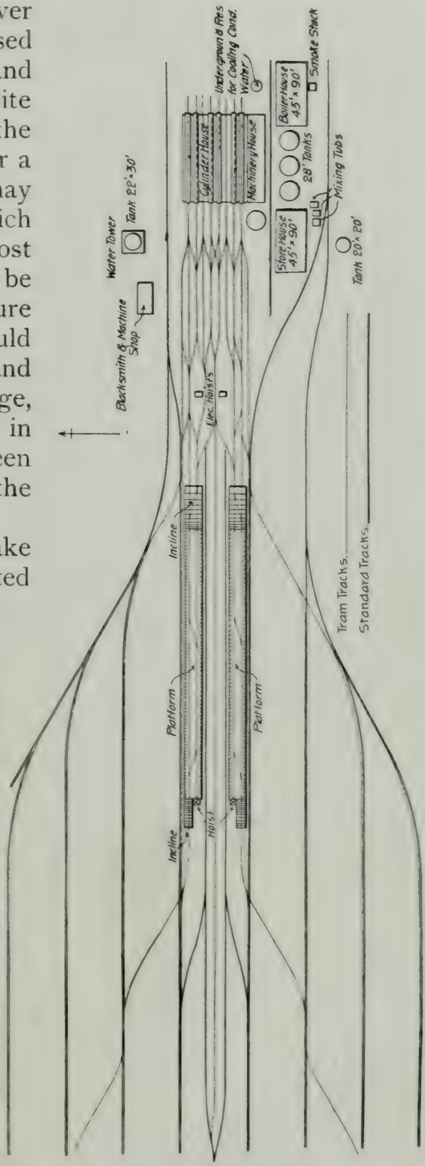
The last qualification it possesses in even greater degree than burnettizing; but its record as to efficiency is not yet clear.

The cost of treatment by the various methods, not including depreciation, interest, or profit, may be taken as follows:

Burnettizing.	3¾	cents per cubic foot.
Zinc tannin.	5.0	" " " "
Zinc creosote.	7.5	" " " "
12-pound creosote.	15.0	" " " "

It is safe to say that whenever an inferior tie can be purchased and treated by burnettizing, and then costs no more than a white oak or other first-class tie, the adoption of treatment by that or a better process is justified. It may not be possible to determine which particular treatment is the most profitable but this should not be considered as justifying the failure to begin treatment. A plant should be designed to treat by either, and if the future necessitates a change, this can be readily made; and in the meanwhile, whichever has been adopted, it is reasonably certain the results will be worth the cost.

The timbers which readily take treatment, and which when treated will make a valuable tie, include the inferior oaks, beech, hemlock, pine, spruce, fir and probably gum. A timber treating plant consists of a cylinder in which to place the timber, means for steaming, creating a vacuum and applying hydraulic pressure to it. Elaborating a little on this, it is desirable to have means of opening and closing the cylinder quickly and tightly and of handling the material in and out quickly and cheaply. The cylinders in general use are about 6 feet in diameter and from 110 to 125 feet long. They must be strong enough to withstand an



internal pressure of 100 pounds or more per square inch, and an external pressure due to a vacuum of 26 or 28 inches of mercury. They must be anchored at the middle to prevent their displacement, and free to move from the center towards the ends under large changes in temperature. The cylinders are provided with movable doors at one or both ends, hung so as to be moved easily and having a gasket to make a tight joint and means for fastening the door to the end of the cylinder and producing sufficient initial pressure so that under the internal pressure, the joint will not be broken.

Two classes of doors are in general use; one which is made tight by screwing up numerous bolts placed about the rim; the door being hung on hinges or supported on an overhead track; and the other, hung on hinges and having a screw projecting from the center, the nut thereon connecting with numerous levers running to projecting stirrups on the end flange of the cylinder; so arranged that when the nut is run in, a heavy pressure is produced on the gasket through the medium of the levers. The first door is the cheaper in cost, but the second, the so-called spider door, is probably the better for economical and convenient operation. The writer has proposed a spider door, substituting for the very inefficient nut and screw, a hydraulic piston, which he hopes to have an opportunity to build. If such a door can be made at not too large an increase in cost, it will be a very desirable improvement. The present doors are by no means perfect.

To handle the timber into and out of the cylinders, requires suitable tram cars. These are usually of 24 to 30-inch gauge, have about 3 foot 6-inch wheel base and are provided with bent arms to support the timber, which is then chained to them to prevent displacement in handling or in the cylinder. Quite an elaborate system of tracks is required in a large plant to enable the tram cars to be transferred readily from the platforms where the ties are loaded and unloaded, to and from the cylinders. There has been discovered no means of handling ties on a large scale except by pure strength and awkardness. The use of elevated platforms for transfer from car to tram and vice versa naturally follows, but in case the ties when received are not sufficiently seasoned for treatment, it becomes necessary to stack them on the ground and a third rail laid between the standard gauge tracks, give access for the trams to the piles. For handling the loaded trams into and around the cylinders, no better means has been discovered than fixed engines located around the yards, with numerous yard sheaves around which wire cables are carried from the trams to the winding engines. Attempts have been made to do this work with portable locomotives, using air or other motive power, but the conditions of service are not favorable to this method. The stationary engines used have usually been operated by steam, carried underground from the boiler house, distances of from 300 to 800 feet. As these engines are idle much of the time, there is a large loss of power from condensation, the steam pressure being maintained in the pipes all the time. Recently electric engines have been substituted for the steam ones, with very satisfactory results. The actual economy is rather hard to determine, but must necessarily be considerable; while the greater convenience and ease of maintainance is marked.

The general arrangement of a tie treating plant is well illustrated by Figs. 1, 2 and 3.

Fig. 1 is a general plan, showing the buildings and one side of the Carbondale yard. The broad gauge, tram and 3-rail tracks are plainly marked. The relative locations of the various buildings, solution tanks, yard engines and tracks, are shown.

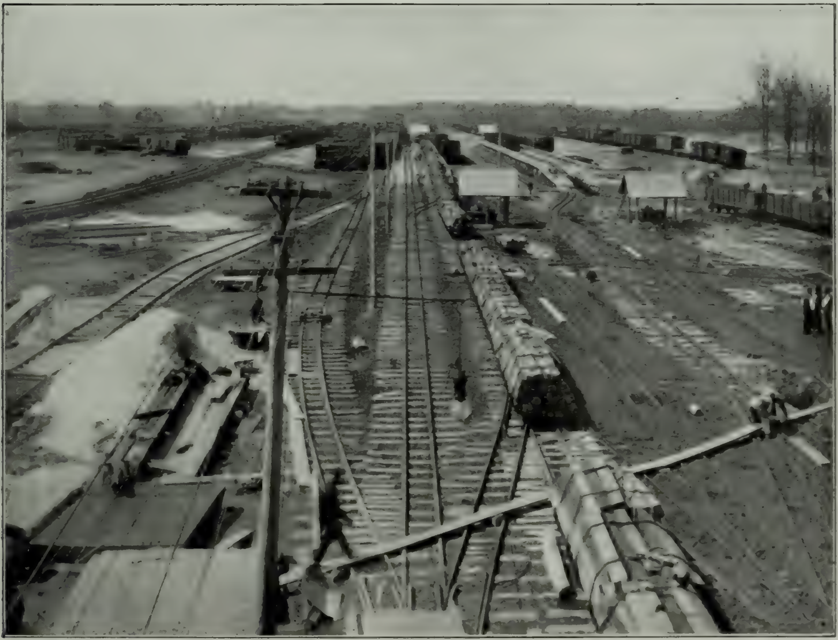


Fig. 2.

Fig. 2 is a view taken from the roof of the engine room, looking down the yard. The two yard engines are in the middle distance, while beyond them are the elevated loading platforms. In the foreground, and extending up on to one platform, are trains of loaded trams, waiting to go into the cylinders. In the distance can be seen piles of ties, awaiting treatment. At the time this picture was taken, in the spring of the year, there were about 400,000 ties piled on the ground; and this reserve has been maintained very uniformly all the year.

Fig. 3 is a view taken at the end of one platform, looking toward the buildings. On the extreme right is the tank in which concentrated zinc chloride is stored. Next, on the left is the store-house, where the supply of fused chloride of zinc is kept, together with such other stores as are required in the maintenance and operation. Beyond are the three solution tanks, of 100,000 gallons capacity each, from which solutions are run into the cylinders. The long, low building in front is the machinery and cylinder house. The ends of the cylinders are not well shown, being concealed by the shadow of a shed roof projecting over the cylinder doors, to protect the workmen from rain. A break is apparent in this roof, which shows where an additional cylinder, the seventh, had just been erected. The elevated tank on the left is part of the water system.

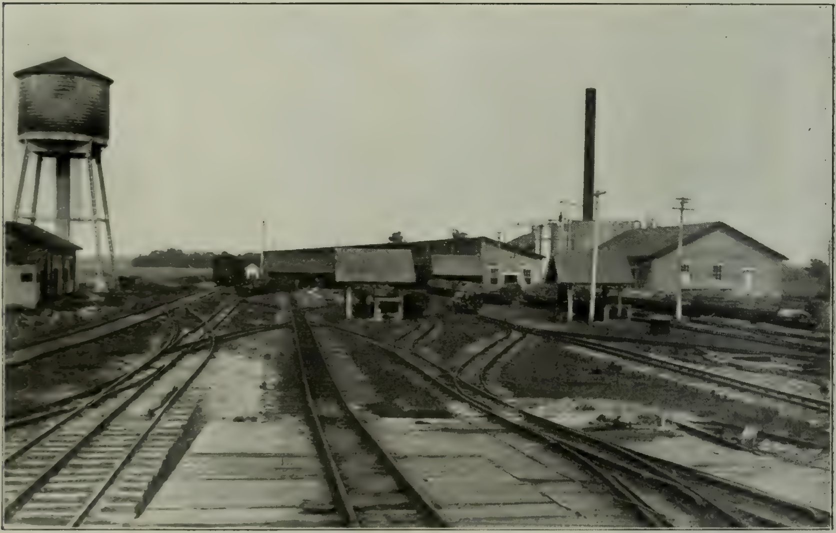


Fig. 3.

Fig. 4 shows the electric engines with which the trains are handled.

Having the material to be treated placed in the cylinders and the doors closed, steam is turned into the cylinders to sterilize it and soften the outer portions in which the gummy substances may have dried. The length of such steaming or seasoning, as it is called, depends upon the character of the wood and the time it has been air seasoned. It will probably be about 3½ hours, during which time the pressure of steam should be held as nearly as possible at 25 pounds. This is supposed to be the highest heat which can be used on wood without danger of injuring it. As steam represents money, the cylinders should be covered with some good non-conductor to make the loss by radiation as small as possible.

After steaming comes the vacuum, produced by some form of pump, aided by a condenser. The vacuum is for the purpose of freeing the timber from its contained air and as much of the water absorbed from steam, as possible. It seems an anamolous condition to so called "season" a tie with steam and have it weigh more after the steaming and vacuum—the seasoning—and before anything has been injected into it, than when first placed in the cylinder. This is a very ordinary condition, however, and is not as absurd as it appears. The moist heat of steam probably insures a more thorough sterilization of the wood, than could be secured with dry heat in the same time and into many woods and under usual conditions, more solution can be injected after such seasoning than without it: but it is certainly desirable to so treat the timber that after the vacuum it shall weigh less than before steaming. The works creosoting for marine exposure find it necessary to use superheated steam, circulated in coils in the cylinders, during vacuum, in order to get the required amount of creosote into the timber. The works treating ties on a

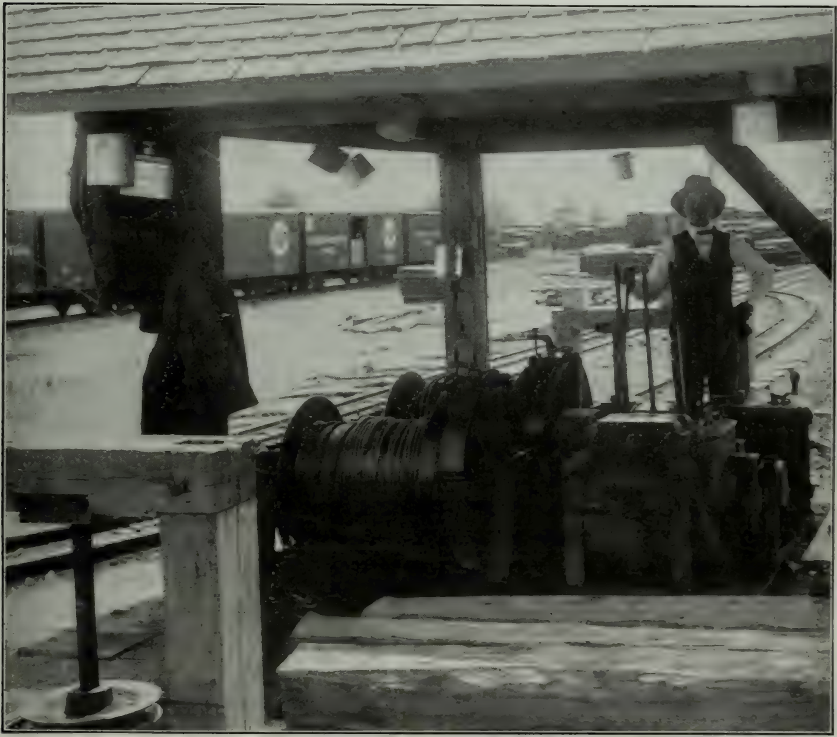


Fig. 4.

large scale do not usually do so. The works at Carbondale, Ill., are equipped with the coils in the cylinders and a superheater, and it is expected to get results which will be interesting and profiitable. The argument for and against the use of superheated steam in coils is this.

After steaming, the ties are saturated to some degree with water therefrom. The water is highly charged with sap and other elements, dissolved out of the wood. It is desirable to withdraw this water and also the air in the wood cells, to make room for the preservative solution. If the temperature in the cylinder is maintained above the vaporing point corresponding to the degree of the vacuum, the water will leave the timber and pass over to the vacuum pump as vapor, and will not depend simply upon the expansion of the air behind it, to force it out. Whatever is forced out in this way remains in the cylinder, to be picked up by the solutions as they come in, and is replaced in the timber. While the temperature of vaporization rapidly lowers as the vacuum is increased, the amount of heat required to maintain this or higher temperature increases, so that a very large amount of area in the coils would be necessary if saturated steam were used. By superheating, the necessary heat can be secured with the use of an amount of pipe it is possible to place in the cylinders. Of coure if the temperature maintained in the timber is less than sufficient to vaporize the water, it is utterly useless.

Those deprecating the use of heat during the vacuum period, say they find when the cylinders are hot, it is impossible to secure a high vacuum as quickly as when cool and consequently instead of turning on steam to maintain the heat, they allow the cylinders to stand for awhile after the direct steaming, before starting the vacuum pump. They also say the results secured by the usual method is satisfactory, so why spend time and fuel for something else?

It would seem that the fact that a high vacuum can be secured in less time when no heat is used, would settle the matter in itself. A condenser is used in either case and if it takes longer to secure the vacuum with the use of heat in the coils, it is because more air, vapor or something, is taken out of the timber. The vacuum is not the end sought for, but only the means to the end.

After the timber has been under the vacuum for a sufficient time, valves are opened in pipes connecting with large tanks containing the preservative fluids, heated to the proper temperature; the tanks are usually elevated sufficiently to secure the rapid filling of the cylinders under the combined head of the vacuum and tank elevation. When entirely full, the direct connection to the tank is closed, and by means of a pump, additional preservative is forced into the cylinder until the desired pressure is secured and this is maintained until the desired absorption is obtained. The amount of absorption will depend upon the character of the timber and its condition, running perhaps 20 per cent by volume for refractory timber to 50 per cent for very dry sap pine.

After the desired amount of preservative has been injected, the surplus in the cylinder is either run off into surface reservoirs and then pumped back into the elevated tanks; or is forced thereto directly by the use of air pressure. The cylinders are then opened, the ties withdrawn, new ones run in, and the operation repeated.

A very elaborate system of pipes and valves, and a number of machines, become necessary, if the treatment is to be given economically and conveniently.

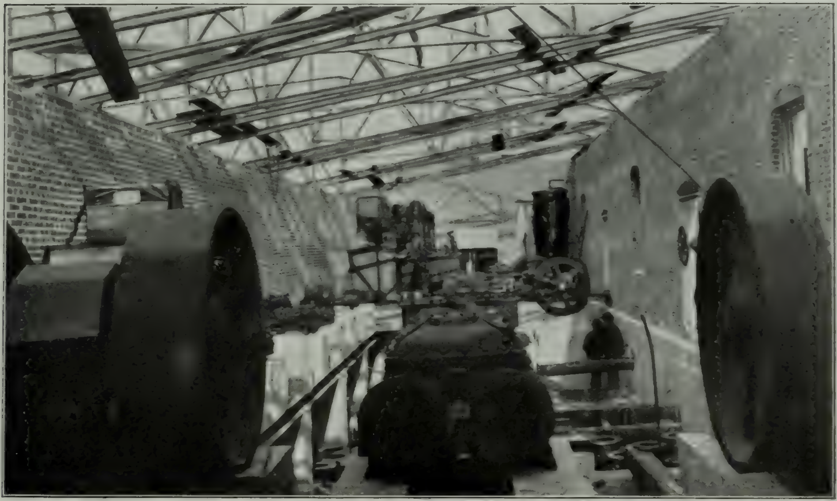


Fig. 5.

Fig. 5 shows the interior of the machinery room during construction. In the foreground are seen two engines, which are used to operate generators supplying electric current for lighting and for the yard engines, water supply pump, and for the machine shop. The pump in the foreground is used to pump solution and for fire protection. Immediately beyond the pump is a pit, shown again in Fig. 6, after it had received its system of pipes. Beyond the pit is an air compressor, used to force solutions from the cylinders into the storage tanks, and to unload the concentrated chloride from tank cars into the proper tank. Beyond the compressor are two fly-wheel vacuum pumps, a feed water heater on the right, and two surface condensers on the left. Along the wall on the left and in the middle foreground are small pressure pumps, one for each cylinder—at present seven in number. When it is considered that it may be necessary to use three different solutions in the treatment, that every cylinder has an independent supply pipe, to which any one of the solutions must be supplied; an independent blowoff and connection to the vacuum pumps and condenser; that each cylinder has its own supply of saturated and superheated steam; and all of these various pipes must be controlled by one man, without leaving the room, it will be understood the piping plan requires some study.

Fig. 6 shows the method of arranging the large solution pipes. Three large headers, at different elevations, may contain different solutions. Pipes from each header run to a cross on the left, set at an angle to connect with the different levels; the opening on the left of the cross receiving the one pipe which runs to the particular cylinder, served by these pipes. The three smaller pipes carry solutions to the suctions of the small pumps, the discharge from which connects to the main supply pipe to the cylinder.

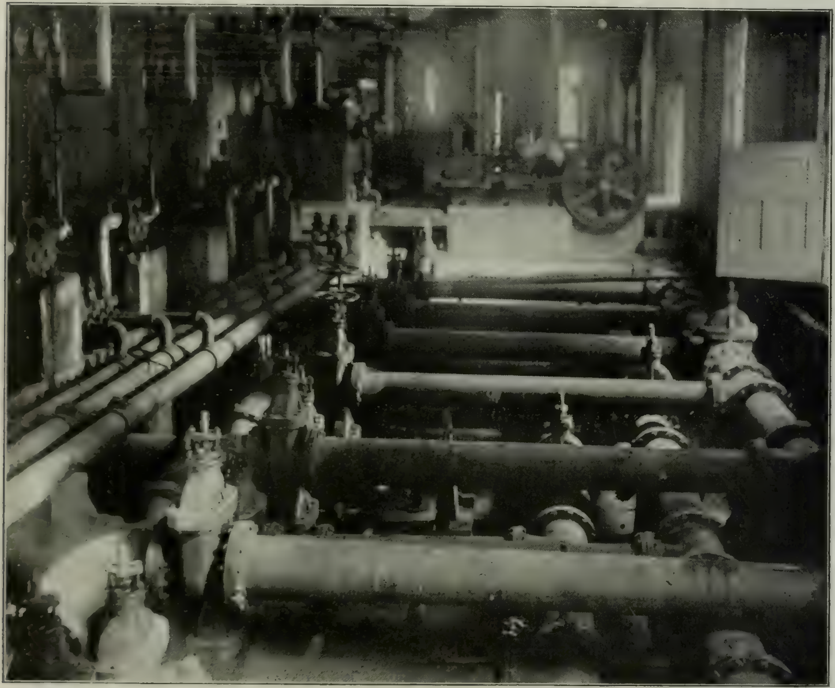


Fig. 6.

Such pipe layouts are the result of the developments of various plants built by various people, with the improvements introduced to meet one difficulty after another, as developed in operation.

Our member, Mr. Samuel M. Rowe, deserves much credit for improvements made in the plants built under his direction, and the writer acknowledges with pleasure the aid he has had from him in the designing of the pipe system.

The usual method of determining the amount of preservative injected is by noting the readings of the gauge on the tanks holding the supplies thereof. The amount of liquid in tank feet, necessary to completely fill the cylinder with empty trams only in it, being known, the reading of the gauge before any liquid is run into the cylinder is taken; a second reading after injection is completed and a third after the surplus is forced back, and all are recorded. The difference between the first and second readings, represents the displacement of the ties in the cylinder; and the difference of the first and third, the amount injected into the ties. A simple calculation then gives the number of cubic feet or gallons injected. In the case of the zinc treatments, knowing the strength of the solutions used, the amount of dry chloride per cubic feet of timber can be readily determined.

There is some dispute as to what this desired amount should be; but the best practice is to inject ½ pound per cubic foot. A much less amount will prevent decay, but the excess does no harm and represents the insurance against the washing out of the zinc during service.

DISCUSSION.

Mr. Parkhurst—What is the length of the cylinders?

Mr. Curtis—125 feet, 4 inches long and 6 feet, 2 inches in least internal diameter?

Mr. Finley—I would like to ask Mr. Curtis for a little information in regard to protecting the cylinders. How are they protected?

Mr. Curtis—These cylinders are covered with a 1-inch layer of magnabestos, which contains about 50 per cent of carbonate of magnesia. However, it has not been customary in tie treating plants to cover them at all. I know of but two tie treating plants where that has been done—the plant at Beaumont, Texas, where the cylinder is covered with a 2-inch thickness of hair, and Mr. Chanute's plant at Mt. Vernon, Ill.

Mr. Parkhurst—What are the gaskets made of that are put in to make an air tight closure at the door?

Mr. Curtis—The gaskets principally used are of braided asbestos. The Southern Pacific Ry. Co. uses a layer of lead 2 inches wide, but I do not think it is as good as the asbestos. The asbestos is used in two or three forms—as a braided rope which is put into this groove and also as a similar rope braided with brass wire. Where you do not use creosote it is possible to use a gasket of rubber and canvas.

Mr. Parkhurst—How long will an asbestos gasket last?

Mr. Curtis—They will last from 3 to 6 months, if well cared for.

Mr. Parkhurst—I saw a canvas gasket a short time ago. It seemed to be a mixture of canvas and woven fibre. It was perhaps 1½ inches wide and the exposed portion of it looked as if it might be a ½ inch thick. I was told that this style of gasket lasted but a short time.

Mr. Curtis—The asbestos gasket is cheap and efficient; it is readily replaced and you can afford to throw them away.

Mr. Parkhurst—I do not recall that you stated how long it takes to pass a charge through one of the cylinders for treating ties.

Mr Curtis—That is a matter depending on various conditions. At Carbondale, in some instances they have put ties through in 6½ hours, and have obtained an excessively heavy injection even then. The time required is 3½ hours for steaming, about 1 hour for vacuum and whatever time is necessary in getting your injection, which, as I said, depends upon the material you are using and upon its condition. If the timber is thoroughly seasoned the time necessary for injection is short, but as a general proposition you can figure about 8 hours for a run, when using the zinc chloride alone. That allows for three runs in 24 hours. If you are using the Wellhouse process it takes perhaps 2 hours longer. In the zinc-creosote process not enough work has been done to gauge the time, but there is no reason why it should take more than 8 or 9 hours. The time necessary for creosoting depends upon the condition and size of your timber—but as in general for a heavy injection, from 18 to 20 hours; if it is a light injection and the timber is small, it may be done in 8, 10 or 12 hours. In the very large cylinders, such as are used at Beaumont, they take 18 to 20 hours on a charge even for burnettizing. They handle with these cylinders a very much larger quantity of material per charge, than in smaller cylinders, but it takes a correspondingly longer time. The only explanation I can see for the increased time is the difficulty in obtaining thorough penetration of the steam, or else the fact that they are using green material. I have never been satisfied, in my own mind, that there was any good reason for the greatly increased time necessary with the large cylinders. I cannot see any advantages from the large cylinders and have never advocated them.

Mr. F. Hollenbeck—How large are your condensers?

Mr. Curtis—Each has 600 square feet of condensing surface. The outside dimensions of the condenser is about 24 inches wide, about 8 or 9 feet long and 4 feet high.

Mr. Geo. M. Mayer—I would like to ask Mr. Curtis whether telegraph poles are treated as well as ties?

Mr. Curtis—Yes. This particular plant that I have told you about is principally for ties, but telegraph poles are treated in exactly the same way; also piles and timbers of all kinds and description. The general custom, however, in the treatment of telegraph poles and piles is to treat them with creosote and not with zinc. The Santa Fe road has for some years treated their piles and timbers with zinc, but I have never been able to get much information as to the success of the process, and I am doubtful of its value, for if the piles are standing in water I think the zinc would not last. It would be dissolved out by the water.

Mr. Mayer—Do you think it would be a good idea to treat only the part of the wood that goes in the ground?

Mr. Curtis—It is not practical to creosote a part of the timber; the whole has to be treated.

Mr. Parkhurst—As compared with creosoting would you advocate the use of those varieties of external applications, for treating timber which is partially buried in the ground?

Mr. Curtis—I think some of those things have a value under some circumstances, but I would not advocate them for ties. Creosote is worth from 6 to 8 cents a gallon and carbolinium avenarius is worth $1 a gallon. Superficial treatment would probably be of some benefit if one cannot treat the timber by forced injection. Of course you cannot inject solution unless you have facilities to do the work, and under these circumstances you might get very desirable results out of these other materials. I do not think however you can get continued satisfactory results by superficial treatment.

Mr. C. F. Loweth—I would like to ask if the creosote can be uniformly distributed throughout a 12 x 12 timber?

Mr. Curtis—That depends upon the amount put in, and the kind of timber. You cannot, if you have heart yellow pine. If it is lob-lolly, which is largely sap wood, you can get a very complete penetration and a very thorough distribution throughout the entire stick, but if you put in only a 12-pound injection you will not get this thorough distribution; it takes more material to fill up the timber. A sap wood timber will take 24 pounds. If you give it the usual treatment you will not get penetration into the middle of a stick with a 12-pound injection.

Mr. Parkhurst—I had a call a few days ago from a man who was advocating one of these solutions to be painted on timber, and he quoted the North-Western (C. & N.-W. Ry.) people as using some of it. I don't remember the exact name for this material, but the man wanted to send me a few gallons with which to experiment.

Mr. E. C. Carter—The material referred to by Mr. Parkhurst was left with the North-Western people (C. & N.-W. Ry.) for experimental purposes, and as it was scarcely six days since, we have no definite results to report.

Mr. Parkhurst—I anticipated as much, but I wanted to verify the statement. Of course I told the man it would take years to determine the value of a process of that kind and that I did not expect we would get any results that would be satisfactory in a short time. However, I agreed to try some of it.

Mr. Carter—It is a question with me whether, in framing timber, as in trestles and the supports for water tanks and in placing braces, a very thorough coating of some such solution or mixture as that, might not have a value in excess of its cost, and it was based on that idea that I consented to make this test as to the penetrating power of the fluid, and after having looked into it that far I thought it might be well to make some experiments on some of our water tanks where the posts and braces decay very rapidly.

Mr. Parkhurst—We have a similar experiment under way where we used 6 to 10 barrels of carbolinium avenarius, but we have as yet no results. It takes time to determine the value of such preparations.

Mr. Carter—I think that is one of the discouraging features of such applications—that long before the time has arrived when you can tell whether the application has any practical value the people who have tried it have passed out, and those who have taken their places either have no information regarding it or no interest in it.

Mr. Finley—I have had occasion to look into a case of this kind, where a compound had been used in a certain location where the timber would, under ordinary conditions, decay very rapidly, and we are of the opinion, from observation, that the material has helped the timber to resist decay. I think that it would be well to apply this preparation to piles at the ground line and I think you could preserve them at that point and extend the life of the pile.

Mr. Curtis—I think the gentlemen are correct in the idea that there is a good field for preparations of that kind, in certain locations. In car building I can see where the benefit could be derived. Whether it would be of value around water stations, I do not know.

Mr. Parkhurst—We have another experiment under way of that kind. A number of large bridges are being constructed, and the joints of the timbers are all thoroughly swabbed or painted with that same material. We may possibly never get any valuable results, but we have started the experiment at any rate.

Mr. Trumbull—I wish to ask Mr. Curtis if he has made any experiments which will indicate the effect of these preservative processes on the tensile strength of timbers and stringers; also on the capacity of ties to hold spikes.

Mr. Curtis—There have been comparatively few tests made to determine the effect of treatment on the tensile strength of timbers. I have differed in opinion with some of our members in times past on this subject. When the treatment was first begun in this country there were repeated failures from stringers and similar material which had been burnettized and which proved very brittle, giving very unsatisfactory results. On that account it has been stated repeatedly that treating by burnettizing processes was injurious to the strength of the timber. I do not believe that to be the fact. The brittleness was probably due to excessive heat. Other tests have been made which show that the strength in bending, at any rate, is not materially affected by burnettizing. The wood is slightly hardened; but that is also a matter of dispute. Mr. Rowe, one of our members, made a trip over a section of road some years ago to see how many of the ties which it was reported had all been taken out, were left, and he found 25 per cent or more still in the track, and in his report he noted particularly the way in which the tie had held up under the rail; the treated tie showed a very marked increased ability to withstand the weight; it was evidently considerably hardened. There are some other data to that effect, but it is something, I think, which has not been proven. I believe treating with zinc chloride slightly hardens the tie. As a matter of fact, I understand that you cannot heat a timber of any kind above 212 degrees without injuring it; it makes no difference how you treat it. It is said that if you heat the wood above 212 degrees there is a breaking down of the structure to a certain extent, but nothing serious, and if you test the pieces of timber not treated and those which have been burnettized, you will find practically no difference or a very small per cent.

As to the question about the effect on spike holding—a spike will hold better in a burnettized tie than an untreated tie. I think that is also true of the creosoting process.

Mr. Trumbull—What would be the effect of an excessive charge of creosoting?

Mr. Curtis—The creosote does not do any harm; the more you put in, the better, except for the increased cost.

Mr. Parkhurst—I have been very much interested in that subject and corresponded with several parties about it. I got a letter from Mr. Rowe, who quoted, if I am not mistaken, some Swedish experiments on the comparative strength of cross-bending, transverse loading, etc., of treated and untreated timber, and while they were too few to give any positive result, the majority of the tests showed an increase in strength of creosoted timber. That is my recollection of the matter.

Mr. Curtis—I heard recently of some creosoted ties which had proved quite brittle. I saw a section of a tie which had been creosoted and which was absolutely brittle. But I know that the ties referred to had been subjected to 300 degrees of heat in treating, and that the particular tie I mentioned had been through 15 treatments with creosote.

Mr. Parkhurst—Mr. Chanute, have you seen any statement of results of timber in regard to strength, after being treated?

Mr. Chanute—I have seen statements of many results that were contradictory. Some parties have stated that the wood was increased in strength by the treatment and certain experiments have proved it, while a few have admitted that the timber was injured in strength by treatment. I think, as Mr. Curtis has stated, that most of the injury that has been done to timber has been on account of overheating, and until we know just how much the timber was heated, we cannot say what has been the further effect of the chemical injection. I am careful, however, in my practice to use as weak solutions as possible, provided we get the desired amount of zinc chloride into the wood. That amount is about ½ pound of the dry salt to the cubic foot, and we vary our solution, making it as weak as we can, and yet injecting as much as we can, in order to keep within the limits of safety.

Mr. Parkhurst—Do you know whether there has been any modification or changes in the sizes of timber used in place of others? Has there been any practical difference made on account of the fact that it was creosoted?

Mr. Chanute—Not to my knowledge; the chief fault I have heard found with creosoted timber was that it was more flammable than timber in its natural state.

Mr. Parkhurst—The statement has been made to me, I do not know with what authority, that after a very short time, a few months perhaps, that inflammable character disappears.

Mr. Curtis—When creosoted material is exposed to the air it very quickly changes and becomes very hard. In fact Mr. Byrnes says that before any creosoted timber is used it ought to be allowed to harden in that way and not to be used before it is exposed to the air for 1 or 2 months. Creosote has, of course, inflammable qualities. It takes a good deal of heat to start it to burn, but when the fire is once started it is difficult to put out.

Mr. Parkhurst—You speak of the necessity of allowing the material to dry and become hardened before using. Is not that impracticable?

Mr. Curtis—It is often impracticable. I have never seen it mentioned in print, and Mr. Byrnes was the first person I have heard mention it, but I believe there is something in it. He spoke of it particularly if you were going to expose the timber to water; there is a certain amount of the material that would wash out.

Mr. Chanute—That question I once put to Mr. Putnam who creosoted the piles between Mobile and New Orleans, and also creosoted the timber that went into the trestle bridges—and he told me that he believed it was more difficult to start a fire on creosoted timber than on timber in its natural state, but that when once it was started it was very difficult to extinguish.

Mr. Mayer—Is there not quite a difference in the life of the ties that are sawed or hewn and then creosoted?

Mr. Curtis—I do not think there is a particle of difference in the treated tie, and as to the other, I am inclined to think that personally I would prefer to have a hewn tie rather than a sawed tie. In the sawed tie you get almost entirely sap wood; in the hewn tie you get young growth wood, which some consider desirable, but when you have treated the tie it makes no difference. As a general proposition, the more sap the tie has in it the more uniformly the wood takes treatment. Another point is, when you are treating ties you do not want to treat the best wood, for if you can make a very satisfactory tie out of an inferior one by treating it, it is cheaper to do that than it is to take a high grade tie and treat it.

Mr. J. S. Robinson—About how much would the age of a good cedar tie be increased by treatment?

Mr. Curtis—Is it not customary to treat cedar ties because they do not decay; they cut out. There is no object in treating cedar ties and it would not be practicable.

Mr. Robinson—What about chestnut timber?

Mr. Curtis—These may have been treated 25 years ago, but such wood is not treated now. Chestnut is another wood not so much subject to decay. It is a long lived wood, and consequently it is not customary to treat it; it is a soft wood, to which the same objection would apply as to the cedar. The chestnut has not the same decay resisting properties, as I understand it, that the cedar has, but still it it a good tie for a soft wood.

Mr. Robinson—I saw some cedar ties on the North-Western road which had been in about 15 years and were perfectly good.

Mr. Curtis—The General Roadmaster of the C., M. & St. P. Ry., Mr. Mohl, told me that they have a track in North Dakota where he knows positively when the ties were put in and knows how many have been taken out, and he is satisfied that these cedar ties are giving them a 20-year life.

Mr. Chanute—In 1887 we treated 3,000 white cedar ties for the Chicago & North-Western Railway between here and Milwaukee, and we concluded that it did not pay to treat that class of timber, as it is naturally lasting, and the increased life would not be sufficient compensation for the increased cost. Some have tested chestnut but it will not take the treatment, being as refractory as white oak.

Mr. Robinson—We have piling that has been in bridges in northern Illinois since 1885—white cedar piling, not treated—and we have renewed oak three times in part of the same structure.

CLOSURE.

Mr. Curtis—Since this paper was prepared, there have been a considerable number of chestnut ties received and treated at the Carbondale plant. As there was no apparent difficulty in securing a satisfactory absorption, Mr. Chanute was asked for his authority for the statement that chestnut ties would not take treatment. His reply referred to pamphlets, issued by two French writers, who had made experiments on their native chestnut timber. It is evident there is either a great difference between our chestnut and the French variety or else some of the results are in serious error. From the appearance of the wood, chestnut would be expected to take treatment very readily, and this has been the experience at Carbondale. There is an appearance of "bridging over" in the vessels, but this is hardly of a character to resist the preliminary steaming and vacuum. I have had a chemical analysis made of a sample of a freshly treated chestnut tie, taken from its geometrical center. This showed 0.32 of 1 per cent by weight, of zinc chloride.

In reply to inquiries as to the output of the Carbondale plant, the following monthly figures are given, the plant being first started in April:

May	211,500 ties.
June	225,000 "
July	284,700 "
August	251,200 "
September	288,900 "

The larger part of the above were red oak, the balance pine.

Those who wish to read further on the subject of The Preservative Treatment of Timber, are referred to back numbers of the JOURNAL:

Vol. IV, page 283—by S. M. Rowe, M. W. S. E.
Vol. V, page 100—by O. Chanute, M. W. S. E.
Vol. V, page 198—Discusion of preceeding.
Vol. V, page 248—An abstract on this subject.
Vol. V, page 252—Bibliography of "Preservation of Timber."

ED.

CLXXXIV.

THE TIE PROBLEM. WITH SPECIAL REFERENCE TO CONCRETE TIES.

G. H. Kimball, M. Am. Soc. C. E., New York City.

Presented September 16, 1904.

There was published in this country in 1858, by Zerah Colborn and Alexander L. Holley, a report on "The Permanent Way and Coal-Burning Locomotive Boilers of European Railways." Their work was very thoroughly done, and the report consists in a large bound volume that is profusely illustrated. Rails, joints, ties, and all the details of the permanent way of railroads receive a large share of attention. A foreign process for preserving timber for ties and for other purposes is illustrated, and there are cuts of many forms of metal ties then in use. The split switch appears in all its essential features, and the likeness of some of the existing forms of rail joint fixtures to those in this old record seems more than accidental.

It also appears from this report that the Philadelphia & Reading Railroad had a creosoting plant in operation at that time.

The tie question has always been a serious problem, and many curious attempts have been made at its solution. Rail sections have been designed with the object of eliminating the use of ties altogether. Granite blocks have been used for ties. My memory reaches back just far enough to recall the granite blocks with which the Boston & Lowell R. R. (now part of the Boston & Maine system) was originally laid. Reference is made to these facts in order to show that the problem now pressing for solution has engaged the earnest attention of engineers and railroad men from the earliest years with but little real progress toward the desired end.

Reference to the old report just mentioned will show, I think, that excepting the improvement in the form, and increase in the weight of rail sections, we have made very little real progress in the details of track construction in the past forty-five years. We certainly maintain better track than in former years, but what I mean to say is, that we are still using the same materials in the same essential form.

The question of the preservation of timber ties has been prominent for half a century. In recent years it seems to have reached a point where certain processes are practically and commercially possible, *for good tie timber*, but they find favor on only a very few of our railways, and there is nothing to indicate that they will ever be generally adopted. The various kinds of timber that are naturally inferior or unfit for ties do not gain in value by treatment for the reason that, so far as these processes affect the fiber of the timber at all, it is to reduce its strength. The most that can be said, is that the life of the tie is prolonged at a corresponding increase in cost, and the real day of reckoning is only delayed.

What seems to the writer the most serious feature of the whole problem—that of unequal settlement because of eccentric pressure—remains untouched by any plan or process so far proposed.

Metal ties, principally cast, have been used abroad to a large extent for fifty years. It has been a continuous experiment always coming short of success. Recently word has come to us that they are at last to be discarded altogether, and that the European lines are now actually engaged in substituting timber ties.

Many attempts have been made to adapt the forms of metal ties used abroad for use in this country, but all have been experimental, and all have so far failed.

The introduction of rolled and pressed steel shapes for a time seemed to promise better things, but these also have failed to fulfill our expectations and requirements.

Not only is the question of cost of metal ties an objection, but such construction is too light; the ties get no hold in the ballast, and it is found impossible to keep track in line.

Weight and mass are, within certain limits, essential factors in all structures, and steel ties fail entirely in this respect, while the ordinary form of ties is more or less deficient.

There is one function that ties must fulfill that seem to be commonly overlooked in the consideration of new forms. They must support derailed cars and engines until they are off the ends of the ties and actually in the ditch. If they fail in this respect, what would otherwise be an ordinary derailment, without particular damage, becomes a serious wreck. All forms of ties except the old timber tie have failed in this particular.

The splendid development of the railway system in this country has been largely made—at least in the first instance—by the "cheap and easy" process, and "maintenance" has been almost synonymous with re-construction, or a process of making good what should have been done under the original construction account.

The question of maintenance means much to the engineer as well as to the owner and investor, and it means more and more every year. It is no longer true—if indeed, it was ever true—that "the cost of maintenance is independent of the increase in tonnage."

The old "cheap and easy" process is no longer cheap, and the only easy process is to construct as permanently as possible, and then to fully maintain. Apparently we are nearing the turn of the road on the tie problem and the universal question on that topic is, "What next?"

Before I attempt to answer that question let me refer briefly to some of the conditions of the problem. I have already called attention to the need of weight and mass as essential in track construction as well as other structures, and the deficiency of modern track in this respect.

Pressing our inquiry from this point of view a little further, we find in modern track a structure bearing seven inches below the surface, weighing from 150 pounds to 200 pounds per lineal foot and sustaining a load of over 4,000 pounds per lineal foot, moving at a speed of seventy miles or more per hour. Is there no disparity in this comparison?

I think we should thank the men of the mechanical departments for springs and equalizers and their various combinations, for we commonly fail to recognize the value of and necessity for such appliances.

The construction of modern track has not kept pace with other improvements, and the demands of weight and speed. Rails only have increased in weight, but as we have gained in section we have lost in quality. In the quantity or quality of ballast there has been little or no change. As to ties the number to the rail length has rarely been increased, while in size and quality we have steadily lost for some years past. As to lack of skilled track labor in recent years, experience seems to be uniform. The principal lines hardly maintain their standards, while the cost per mile for roadbed and track labor is not going down. To what extent this condition of things is affected by the tie question remains to be seen.

Walk track with me now for a time and note particularly what we find. You may make your own choice and take any line of railroad that you please. As I walk along near the ends of the ties I find that they are slightly depressed or are actually loose beneath my tread. Further examination shows that the *ends* of *all* the ties are loose in the bed, and the passage of a train shows a marked deflection of the ends of the ties, the centers bearing firmly. It is plain that the track is "center-bound," not seriously, but still "center-bound," and not from center tamping. All track rules and all good practice prohibit center tamping.

It is safe to say that there is not a rail length of track in this broad land that has been "surfaced up" over a week that is not center-bound in this sense. It is quite impossible for it to be otherwise and the reason is not far to seek.

The ties extend about eighteen inches outside of the center of the rails and about thirty inches inside, referring to each rail separately, of course, as a center of pressure. With reference to the centers of pressure the base of the tie presents more bearing surface inside of the rail than it does outside and it must settle unequally. In other words the center of pressure and the center of figure of the bearing surface do not coincide. In other structures resting on an earth base such an adjustment would be condemned. It is manifest that every pair of wheels must depress the ends of every tie, and that a corresponding series of undulations is set up in the surface of the rails, so that each pair of wheels travels continually in the trough of a wave. This absorbs power to an extent that is not a negligible quantity.

If we push our examination a little further we find that the base of the rails is cutting into the ties, and that this cutting action is greatest at the outer edge of the base of the rail, so that on straight and level track the rails have taken a permanent position with the vertical center lines of the sections inclined outward. This inclination will vary in amount but is always present in track that has been laid for any length of time. Measurements readily show it and it is frequently visible to the unaided eye. This cutting action is caused by the bending of the ties in their bed under the passage of trains, as has just been described. Tie plates are not in general use, but when tie plates are used the cutting action of the rail is eliminated while the inclined position of the rail under load continues. In my judgment broken rails are seldom, if ever, caused by vertical pressure, but are caused by the lateral stress developed with the rails in the inclined position. With our present form of track construction this is unavoidable.

This brings me to the real question involved in the subject of this paper.

I have attempted to design a tie that should not only be permanent in character but one that will meet all the objections referred to and have some other advantage as well. It is first assumed that the center of pressure, and the center of figure of the base of the tie must coincide. Second, existing forms should be adhered to as far as possible without disadvantage. Third, that concrete and steel are suitable materials, when properly proportioned and combined, with provision for distributing pressure and cushioning shocks, to fulfill all the requirements.

This has been accomplished by making a two-part tie with the parts rigidly connected.

In section the tie is the same as that of a "pole" tie seven inches thick and nine-inch face. The center of the tie is cut away, or omitted, for a length of one foot eleven inches, so that we have two blocks of concrete of the 7 x 9-inch "pole" tie section, each three feet long, centering under each rail. These blocks of concrete are moulded on the ends of a pair of 3-inch steel channels, 7 feet 11 inches long, which are placed back to back and spaced 2 inches apart in the clear.

Hardwood blocks 3 inches thick by 9 inches wide and 18 inches long, designed to cushion shocks, distribute pressure and serve as spiking blocks, are secured to the top of the concrete blocks. Each hardwood block is, of course, centered with reference to the line of the rail. Cast iron sockets that also serve to space and connect the channels are moulded in place in the concrete, and serve as an anchorage for holding down the hardwood blocks.

These sockets receive a suitable bolt, head down, so that when it is slipped to its place, and the opening through which it was introduced has been plugged, it cannot be withdrawn by ordinary means. Water must be excluded from these sockets and they are therefore sealed with pitch.

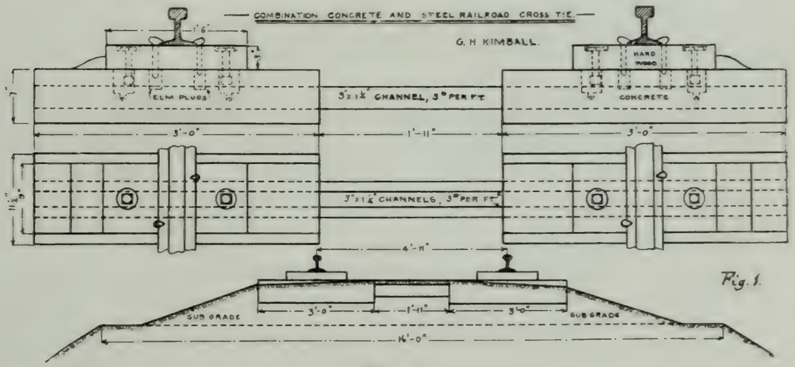


Fig. 1.

The top sides of the hardwood blocks are counterbored to receive the nut so it will be flush with the top surface, and this cavity is also sealed in the same manner after the nut has been set up with a socket wrench. Properly preserved these hardwood blocks will last as long as the rails and in general will only need to be renewed as new steel is laid. The exposed portion of the channels between the concrete blocks is preserved with a wash of pure Portland cement. Elm plugs are embedded in the concrete to receive the points of the spikes. These are on the end of the grain and have a ⅜-inch hole through the center which corresponds with a ⅜-inch hole in the hardwood blocks. The size, number and arrangement of the plugs and holes can be made to suit circumstances. There is reason to believe that spikes will hold better when driven through and guided by a small hole than when driven in the solid wood. Straight spiking is a necessity and is thereby assured.

As to the mixture for the concrete blocks, good ordinary concrete of native Portland cement answers all requirements. Broken stone can be used or any material from coarse sharp sand and pebbles, to medium gravel.

All the ties made up to date have been of concrete mixed in the following proportions:

Broken stone concrete.

Cement, 6 parts	6
Broken stone, 11 parts	14
Sand or fine gravel, 3 parts	
Total	20

The broken stone passed through a 1 ½-inch screen and was clean and free from dust.

Gravel concrete.

Cement, 6 parts	6
Medium gravel, 14 parts	14
Total	20

None of the pebbles to be larger than 1 ½-inch diameter. Atlas cement was used in every case and the concrete was mixed rather wet.

There are three methods of moulding, all of which are applicable:

First: The machine method using metal moulds with false bottoms and dropping sides, with provision for pneumatic tamping, the same as is now in use for moulding building blocks.

Second: Wooden moulds with bottom and sides in sections, and held together by clamps when in use.

Third: With sand moulds as in a casting floor.

The first method answers for concrete mixed as dry as possible. The second method answers for medium wet concrete, and the third for very wet concrete and fine materials.

In every case the tie is moulded upside down, and a plank (on which are fixed in proper position the plugs and sockets) forms a false bottom for the mould. The steel channels are then supported in place and the mould filled in.

The first tie made was moulded on the ends of a piece of 30-pound rail, and old rail, aside from the question of economy in metal, is as good as anything else for the purpose.

Except in a special case to be referred to, all the ties made have been put in singly between wooden ties, that being the most severe test that could be devised, as the entire concentrated load on each pair of wheels was thus borne by the concrete tie.

There have been no failures, and there have been no changes in the original designs except to reduce the weight of steel from four pounds to three pounds per foot.

The following mechanical tests have been made:

A concrete block containing channels was placed on supports, spaced two feet in the clear and pressure applied on the head of a rail bearing on a wooden block the same as if laid in track. Failure began with a maximum load of 90,000 pounds; only a faint crack appeared and the tie remained in serviceable condition.

The second test was made to determine the adhesion of concrete on steel, and pressure was applied to slip the channels through the concrete block.

The block was one foot long and required 78,000 pounds to start the channels, equal to 303 pounds per square inch of concrete and metal surface.

A block of broken stone concrete containing channels was placed within a large box filled with gravel so that the ultimate strength might be obtained under conditions somewhat like those in actual service. This block failed under a load of 82,400 pounds.

A second block of gravel concrete *without* channels, tested under the same conditions, failed under a load of 143,600 pounds.

It is a singular fact that in both these tests the concrete did not fail by fracture transversely as would be expected, but split longitudinally.

The first tests were made in the machine shop with an ordinary wheel press.

The last two tests were made by Robt. W. Hunt & Co.

The estimated cost and weight of the tie are as follows:

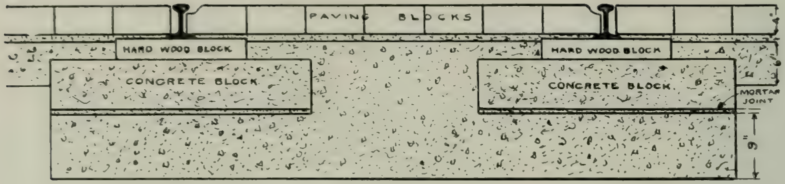
Iron and steel	$0.58	52 pounds
Concrete	0.50	374 "
Wood blocks	0.12	10 "
Royalty	0.10	....
Total	$1.30	436 pounds

The cost figures are based upon a normal or average market, and the cheapest grade of steel obtainable is supposed to be used.

Besides its use in ordinary track the concrete tie has two other valuable applications, as follows: For use in streets, paved or unpaved, where drainage is poor or impossible, for subways, tunnels, and in place of ballast for bridge floors.

The Pere Marquette R. R. laid on Jefferson Avenue, Bay City, Mich., in 1902, 3,400 feet of single track on concrete ties.

The track occupied the center of the avenue, which was to be paved. In connection with the paving a 9-inch course of concrete 8 feet wide was put down for the track foundation, and on that con-



CROSS SECTION of STREET PAVING AT BAY CITY, MICHIGAN Fig. 2

Showing P.M.R.R. Track Construction with CONCRETE TIE on CONCRETE FOUNDATION.

G. H. KIMBALL.

crete ties were laid, being bedded with a joint of cement mortar and set to grade with a level.*

After the track was laid and the sides of the street paved the track was filled in with concrete and paved. The wood blocks were treated with carbolineum.

The result so far is highly satisfactory, and while all things depend upon the test of time, the worst that can happen will be the renewal of the hardwood blocks, and that at long intervals.

One more application of this idea remains to be mentioned.

The difficulties of maintaining track on ballasted bridge floors, and preventing corrosion of the metal surfaces that are particularly exposed under such conditions, are well known. My proposal in this connection is simply to fill in with concrete, wholly or in part, the pocket or cell that commonly holds the ballast, and to form the upper surface of the concrete to hold the hardwood blocks for the rail surface, as before.

The track thus becomes an integral part of the structure; is actually permanent within the limits of the life of the rail—which is thereby increased—and the effects of impact and vibrations are reduced to a minimum.

In designing new structures, provision should be made to nearly fill the pockets with concrete. Because of the perfect support thus afforded for the web and bottom plates of the floor, more than enough saving can be made in the ordinary sections to provide for the increased dead load.

In designing such floors, the distance between centers of cells should be an even divisor of the rail length, so that all the joints may be supported or suspended, and all fully spiked. So far no attention seems to have been paid to this important detail.

The preservative property of cement and concrete does not seem to be generally understood, or if understood is rarely applied. It is only necessary to remove loose scale and foreign material to secure the best results. An incidental advantage in treating such structures in the way proposed, consists in the fact that the heavy rumbling noise so objectionable in towns and cities, will be largely diminished.

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* The blocks of concrete may be tied together with channels as shown in Fig. 1 if thought desirable, but this seems hardly necessary when bedded in the concrete of the sub-pavement, as shown.

In general, concrete ties can be made to the best advantage on the line of the road using them, and at or near the source of supply of the broken stone or gravel. There are also various other materials, like the waste from zinc and copper mines, that will make good concrete where gravel and stone are not readily available.

The advantages to be derived from this form of construction may be summed up as follows:

Economy in fuel consumption (or what is the same thing, an increase in train tonnage), and reduction in the cost of running repairs of locomotives and cars, both due to perfectly smooth track that will not yield unequally. It is true that these factors can never be measured, but that they are real and of substantial magnitude will not be disputed by men near enough to present every-day conditions to realize what they mean.

The chief advantage, of course, is in eliminating the cost of tie renewals, but there is no item of expense under the head of road-bed and track labor, or of the materials handled in that connection, that is not favorably affected to a greater or less degree. The fact that it will no longer be necessary to break the bed below the tie means much in saving of labor as well as in maintaining the best track, with the added advantage of preventing waste and wear of ballast.

Perfect adjustment of the load to the bearing surface of the rail on the tie, and of the pressure on the base of the tie to the conditions of the road-bed are permitted and required. The reasons for exact adjustment of these details are as weighty as those for the proper distribution of pressure in other structures. Under such conditions the settlement of track would be uniform and would be reduced to a minimum.

The simple fact alone that even spacing of ties becomes imperative goes far towards securing the best results in high-class track, while with joints better maintained we may confidently expect an increased length of life for rails. Shimming and adzing will be reduced to a minimum and aside from that due to heaving, will entirely disappear.

A further advantage is obtained by preventing the widening of the gauge on tie plates, and both the widening of the gauge and cutting of the ties where tie plates are not used, this action being due to the springing of the ties referred to and the consequent canting of the rails outward from the vertical when under load.

Increased stability due to greater weight of track construction is a decided advantage, and doubling the end area embedded in the ballast will prevent change of alignment, while better surface drainage and greater freedom from snow within a wide range of latitude due to elevating the base of the rail 4 inches or more above the ordinary level of the ballast, contribute largely to the general result.

It also insures the best insulation for bonded track.

Necessary variations in detail to suit local conditions are easy of adjustment.

With track once laid on concrete ties an arbitrary reduction of section force can be made, and there is no standpoint from which the question can be viewed, except that of limiting present expenditure regardless of ultimate economy, that does not promise a large saving in maintenance-of-way charges.

ADDENDA.

Mr. Kimball writes that he has had intimate connection with track work for more than twenty years, filling positions from roadmaster to chief engineer, and that the design presented in this paper is the outcome of his observation and experience. It has been severely tested for about two years, and without any indication of failure. Mr. Frank H. Alfred, Chief Engineer of the Pere Marquette R. R., writes:

> "The results so far with the track in Jefferson St., Bay City, are very satisfactory. * * The weight of our consolidation engines, with tender loaded, is 136½ tons—37,000 pounds on each pair of (driving) wheels."

Mr. Kimball adds that there are some engines in use on that railroad that concentrate 51,000 pounds on a pair of driving wheels. Also that there are twenty to thirty patents in the United States on concrete ties, and nothing has been done under them. Some patents have already expired, yet nothing was done during their life. It appears some work on concrete ties has been done in Italy, as indicated in the following abstract:

> "The Adriatic Railway (of Italy), is trying an armored concrete railway tie on its lines.
>
> "Before adopting this tie numerous tests were made by the engineers of the road of a great number of railway ties submitted to the company. The tie is 85 inches long and weighs 286 pounds. 121 pounds of cement and 165 pounds of sand are consumed in the manufacture of each tie.
>
> "The aggregate cross-section of the twenty-eight bars contained in the tie equals three square inches. These ties have been in use since July, 1900, on the Ancona branch of the road, and are giving excellent satisfaction.
>
> "The cost of manufacture ranges from $2.16 to $2.40 per tie. The life of these ties is estimated at from thirty to forty years, while the life of wooden ties is estimated at from ten to fifteen years under the most favorable conditions, and cost in Italy from 75 cents to $1.00 each. These figures show that the use of the armored concrete tie will reduce the fixed charges on maintenance of way, and are therefore to be preferred."

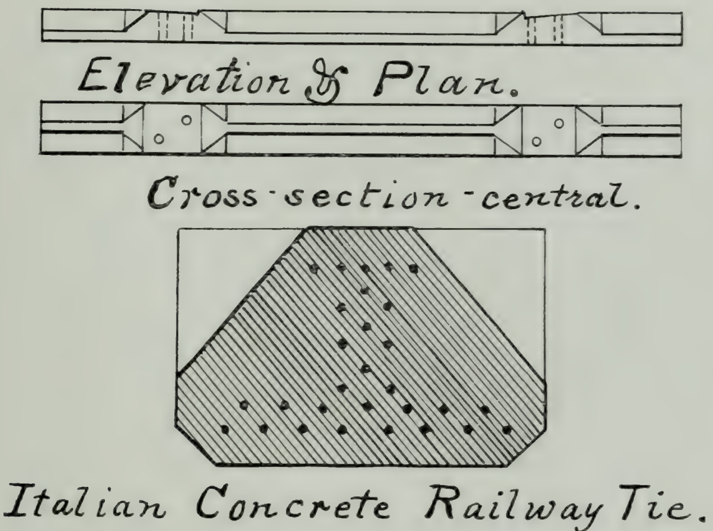

Fig. 3.

This sketch illustrates the concrete ties under trial on the Adriatic Railway of Italy. The rail seats are inclined, that the head of the rail may conform to the coned tread of the wheels.

DISCUSSION.

Mr. W. S. Dawley, M. W. S. E. Anything in the shape of a tie which Mr. Kimball, or anyone else, can suggest that will be permanent and will have but a reasonable cost, is of very great interest to the railroad world.

The treating by Burnettizing, creosoting, etc., of the inferior woods of the country will without doubt go some distance in solving this problem, but I think we all recognize that it is only a question of time until there will be a very serious shortage in track tie material even if inferior oaks, beech, etc., are used and treated.

The Chicago & Eastern Illinois Railroad Company have treated about 800,000 ties in the past five years and expect to continue the practice. While we have not had these ties in track long enough to say positively what their life after treatment will be, we do know that of 800,000 put in track less than one hundred have been taken out because of showing any signs of decay, and we do know, also, that the material used—mixed oaks, known locally as red oaks, water oaks, jack oaks, etc., which we used for treatment, would not last under the best of conditions four years without treatment, and not an average of over three years. A sample lot of one hundred was put in our track just south of the Chicago city limits in June, 1898, and a careful examination only a short time ago showed every tie there and in first-class preservation.

Mr. W. W. Curtis, M. W. S. E.—Mr. Kimball's statements regarding the preservation of timber ties are hardly accurate. Certain processes are not only practical and commercially possible for good tie timber, but also for very poor tie timber, making a valuable tie out of a very inferior one. The few roads with which they find sufficient favor to be largely used are at least 15 in number, and the number of treated ties used by them this year will probably be 10,000,000 or 12,000,000. So far as I know, no reports have ever been made of the number of ties yearly treated by all plants, but the figure given are probably not very far from correct. Considering the fact that five years ago only 3 of the 15 roads included above, were using treated ties, it would appear that timber preservation is not in such a comatose condition as the author would indicate.

Mr. Kimball's tie seems to be a good one, except that, to keep down the cost he has introduced some very light iron. The 3-inch channels used, apparently have a web about $\frac{5}{32}$-inch thick. While no doubt Portland cement is a good protection against rust, it is only so, as long as it remains intact, in a continuous surface. If I was using such ties, I think I would prefer to be a little more generous in my use of metal or else place it in a different shape. A 6-pound round bar or a T-bar would seem to offer more assurance of permanency than two 3-inch channel sections. The estimated cost of the tie is hardly fair. A price of 1.1c per pound for the metal—light channels, bolts and washers—can hardly be called normal. At present prices this tie would cost about $1.63. It would seem

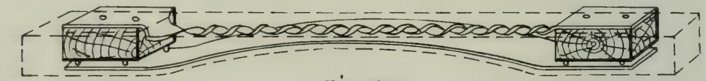

Fig. 1.

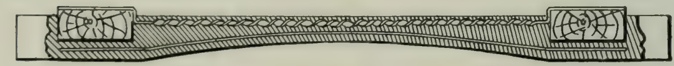

Fig. 2.

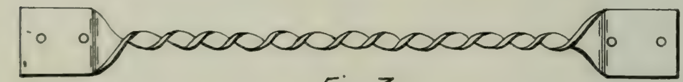

Fig. 3.

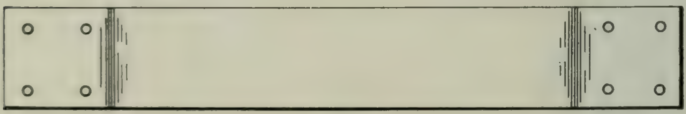

Fig. 4.

The Burkank Tie.

rather a hopeless undertaking to attempt to persuade the American railroads to invest in ties at this cost.

Mr. Warder, M. W. S. E.—Another form of concrete cross-tie for railway use has been devised by Mr. Burbank, of Bay City, Mich., which is herewith illustrated. From the patent specifications and the technical journals the following description has been prepared. The concrete tie is moulded around and about two metallic members, shown by Fig. 3 and Fig. 4. These are flat plates, the upper of which is twisted. Wooden blocks are used under the rails, and partially bedded in the concrete. The ends of the top plate are carried over these blocks, thus protecting them from any cutting action of the base of the rail. Spike holes are punched in proper position in the ends of this top plate for the rail spikes. The top plate thus serves to hold the rails to gauge. The ends of the lower plate are provided with metallic pins fast to the plate, which serve as anchors to lock the plate in the concrete.

The lower plate is bent upward as shown, and the mass of the concrete is lightened at the central portion of the tie. It is not known that these ties have been used to any great extent and no data is at hand as to their durability under services.

Mr. O. Chanute, M. W. S. E.—The author of this paper is mistaken in his assumption that there is nothing to indicate that preserved ties will ever be generally adopted in this country. Creosoted beech ties last 27 to 30 years in French tracks. Creosoted pine lasts 15 to 20 years in England, and Burnettized pine, hemlock, and red oak show a life of 10 to 15 years in this country; the life being in almost direct proportion to the cost incurred in the treatment.

Nor is it true that inferior timbers do not gain in value by treatment, for the reason given that so far as these processes affect the fiber of the timber at all, it is to reduce its strength. On the contrary it is the inferior timber ties which it is best to treat. Their life is trippled, and there have been no complaints of breakages with many millions of ties laid.

Metal ties are not "principally cast," nor do the European lines propose to discard them altogether. It is well, however, to seek for a better and more economical way of supporting the rail, if one can be developed. Just now inventors are turning their attention to concrete ties, and the author is mistaken in his assertion that nothing has been done under the 20 or 30 patents taken out. The technical papers have published several accounts of the experiments and it is hoped that some of the parties interested in the subject will avail themselves of the present opportunity to advise the Western Society of Engineers, as to what has been accomplished. With respect to the author's own proposal, its merits will finally have to be determined by experience. That trial which he adduces of 3,400 feet of single track laid last year on the Pere Marquette R. R. is not to the point, for the construction shown, i. e.: a solid bed of concrete supporting concrete blocks, is much too expensive to be adopted elsewhere than upon a few streets. It is not stated how many of the single concrete ties have been put between wooden ties, nor how long tested, nor what have been the results, except that "there have been no failures." We are therefore compelled to examine the proposal upon its theoretical merits.

It seems to be a suggestion to return to the system of blocks which supported the rails on the railroads first built. This system consisted of stone blocks two feet square and one foot thick laid under each rail, a cast iron chair being fastened by wooden pegs driven into holes bored in the stone block. These were soon entirely discarded because of their rigidity and it remains to be seen whether the concrete blocks, three feet long, nine inches wide and seven inches thick, proposed by the author, will do any better. Some elasticity will doubtless be imparted by the surmounting wooden block, but this raises the top of the rail some ten inches above the connecting channel, and unpleasant results will follow whenever a wheel is derailed.

Neither is it to be expected that the settlement will be uniform, and that it will no longer be necessary to break the bed below the tie to keep the rail in surface. Frost and passing trains will produce unequal settling. There probably will be no center binding but there will be broken rails. However, as stated before, the merits of all new proposals will have to be determined by experience. The first cost and the average life in service are the principal factors which settle the economy. It is well in this connection to call attention to the Amortization tables for computing annual charges of initial expenditures, published by Mr. B. E. Fernow in Bulletin No. 9 of the U. S. Department of Agriculture.* This indicates, for instance, that if a concrete tie lasts 30 years, and costs $1.50 laid in the track the annual charge, with 5 per cent interest, will be $9.74, while on a wooden tie, lasting 11 years and costing 75 cents laid in the track, at the same rate of interest, the charge will be $9.01 a year. If it lasts 14 years the annual charge will be $7.57 a year.

Mr. H. H. Ross, Jun. M. W. S. E.—I would like to know why Mr. Kimball thinks it necessary to use spikes in a concrete tie, and why is wood to be considered at all. My observation has been that the spike is the weak spot in all track work, and even with the best oak the edge of the rail soon cuts into the tie and requires constant maintenance to keep the track to line and gauge. It seems to me a solid metal surface is much to be preferred. The rail can be fastened as easily by means of clip bolts as by spikes, and the cost will be but slightly more.

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*See pages 598-601.

A very fine tie to my mind is now being made by Mr. C. Buhrer, Roadmaster for the L. S. & M. S. Ry. at Sandusky, Ohio. I have recently examined ties of this style that have been in our track (L. S. & M. S. Ry.) for some time and cannot see but that they are exactly as good as the day they were put in. The track is in very fine line and surface, and I am told by the section men that the work of maintaining the track is very much less with these ties than with oak ties. I am told that these ties are now being tried by six different railroads—20 on L. E. & W. Ry., 40 on L. S. & M. S. Ry. at ten different points on the system, 550 on the Lakeside & Marblehead Ry. on a 12 degree curve at Danbury, Ohio, 77 on the Ann Arbor R. R. on a 5 degree curve near Durand, Mich., 15 on the C. & N.-W. Ry. near Milwaukee, and 50 on the Pennsylvania R. R. seven miles from Toledo.

The Pennsylvania Company consider this the best piece of track on their system. These ties have been in their track for several months and I understand the Pennsylvania people are to make a test on a much larger scale, and have ordered a mile of track to be laid with these ties on stone ballast.

Our own experience, so far, with these ties is that the track stays to line, gauge and grade much better than with wooden ties, mainly due to the rigid fastening and solid bearing for the rail.

Mr. E. E. R. Tratman, M. W. S. E.—Before taking up the discussion of the paper I would explain that the inclining of the rail seat of the Italian concrete tie, shown in the illustration, is in accordance with general European railway practice. The tires of the wheels have an inclination or coning of 1 in 20 (as against 1 in 38 in this country), and the rail seats of ties, rail chairs, or metal tie-plates are given a similar inclination so as to give the wheel tread a proper bearing on the rail head.

Mr. Kimball very much underestimates the value of and the extensive use of preservative processes which make ties of inferior timbers practically equivalent to untreated hardwood ties. The number of plants in operation and the number of treated ties in use, together with the records of life of these ties, are evidence of the actual value and economy of ties of cheap and inferior timber when treated by preservative processes. He remarks that these processes find favor only on a few railways, but most of these are important roads with large mileage and using an enormous number of ties. Several lumber companies have also put in treating plants, to supply ties to railways which do not care to establish plants of their own.

One of the greatest advantages in the treating processes is that the inferior classes of timber, which would be of no value for ties unless treated, are by the treatment made practically as good as the best hardwood ties at the same or even less cost. The increase in cost of tie is not proportional to the increase in life, and the preservative process practically introduces an entirely new supply of timber ties. The use of treated ties is certainly extending.

It is unfortunate that in the introductory part of the paper the status of the metal tie is erroneously stated. The author said that metal ties "principally cast," have been in use for fifty years. But in 1894, there were nearly 22,000 miles of line laid with steel, as against 12,375 with cast iron. The latter are also mainly used under special conditions or climate, soil and animal life; that is, where salt air or a saline soil cause corrosion of steel, or where white ants destroy wood. It would certainly be incorrect to infer from Mr. Kimball's remark that word has come that metal ties are to be discarded altogether on these 34,000 miles of track. It is undoubtedly true that in certain isolated cases metal ties, old and of inferior design, are being replaced with wooden ties; but that is offset by the continual introduction of new metal ties. It is also true that nearly all experiments in this country have been unsuccessful. But these experiments have been very limited; tens of ties having been laid here for experiment, while thousands have been laid in other countries for regular use. Probably the only steel ties now in use in this country are 150 ties on the Lake Shore & Michigan Southern Ry., built up from old rails with plates riveted on, according to the designs of Mr. Buhrer, Roadmaster, of Sandusky.

The manufacture of metal ties is an important item in the steel industry of Germany, Belgium and other European countries, both for domestic use and for export. Steel ties are not used in England, but they are manufactured extensively in that country for colonial and foreign railways. A partial record of advertisements in an English paper by railways inviting bids for such ties was kept from 1896 to 1901, and this very incomplete record showed 55 contracts, of which 49 were for India, 3 for Mexico and 3 for Africa. In most cases the quantities were not stated. In some cases, however, the quantities ranged from 6,000 to 100,000 steel ties per contract and from 520 to 12,000 tons of cast-iron ties per contract, the former being sold by number and the latter by weight. That represents manufacture in England alone, but the business is probably greater than this in other countries.

It is rather too sweeping a statement to say that metal ties are too light, get no hold in the ballast, and do not keep in line. Certain ties may be open to these objections, but they do not apply to metal ties in general. And steel ties have sustained derailed trains in many cases.

Probably the first practical experiments with concrete ties in this country were made a few years ago in Chicago. In June, 1899, thirty ties of a pattern invented by Mr. C. C. Harrell were laid in the west bound main track of the Pennsylvania Lines, just north of Harrison street. They were laid on a curve of 3½ degrees, in stone ballast, and carrying 85-pound rails. The trains passed at very slow speed. In two weeks after being laid, two were removed, being in shattered condition, with the concrete separating from the steel. These ties were replaced with new ones. In December, 1899, the ties were examined, and ten of them were found to be cracked, two being badly cracked. In April, 1900, they were all removed, owing to failure of the rail attachments, the bolts working loose and causing disintegration of the concrete. It was doubted whether they would have stood so long under fast traffic. The ties were 7 feet 4 inches long on the bottom, 8½ inches to 12 inches deep, 10 inches wide under the rail and 5 inches wide at the middle. The steel work was a simple truss, with horizontal top chord, inclined bottom chord and a strut at the middle of the tie. The design was afterward modified by Mr. J. J. Harrell, who used two steel channels 7 feet long, in the top and bottom of the tie, separated by distance pieces, and having vertical and inclined struts between them under the rails. A short piece of steel channel formed each rail seat, and through this passed the anchor bolts, whose heads were under the rail seats. The rail rested on a shim or packing plate and was held by clamps fitting the rail base and held by nuts on the bolts. This tie was 7 feet 8 inches long, 8 inches deep, 5 inches wide at top and 8 inches on the bottom; it weighed about 300 pounds. In 1901 still another form of the Harrell tie was designed. This was 8 feet long, 8½ inches deep, 5 inches wide at top and bottom at the middle (for about one-third of its length), and 6 inches wide at top and 9 inches on the bottom at the ends. The steel reinforcement consisted of a single plate of steel set on edge in the middle of the tie. The plate was ¼-inch thick, 7 inches deep and 7 feet 8 inches long, with ends bent at right angles, and the sides having numerous projecting lugs formed by punching holes in the web. This was to effect a complete bond between the steel and the concrete. Each rail seat was a ⅜-inch plate, 5 x 14 inches, resting on the web plate. Two straps riveted to the web passed up through the plate; spring clamps fitted over these and were secured by keys driven (parallel with the rail) through holes in the tops of the straps. The concrete was a wet mixture of Portland cement and ⅝-inch crushed limestone.

The paper describes only Mr. Kimball's form of tie, but at least four different types of concrete steel ties are in use in this country; (1) the Kimball tie, on the Pere Marquette R. R.; (2) the Buhrer tie, on the Lake Shore & Michigan Southern Ry., the Pennsylvania R. R. and the Lakeside & Marblehead Ry. for two or three years;

(3) the Hickey tie, on the Michigan Central R. R. for three years; (4) the Burbank tie, on the Hecla Belt Line Ry., Bay City, Mich., since May, 1903. However, the number of ties is so limited and the experience so short, that as yet they afford little information as to their ultimate value. The same may be said of the ties on the Adriatic Ry., in Italy. A few of these have been in use for about three years near Ancona. The section is approximately triangular, with sides 8 inches wide, except that at the rail seats the section is rectangular. The weight is about 258 pounds, of which the steel bars represent 88 pounds. If they were laid apex downward, as has been suggested, they would probably rock under the traffic, as was found to be the case with triangular and semi-cylindrical wooden ties many years ago.

Mr. Kimball does not say how many of his ties are in use, where, or for how long. His concrete ties at Bay City (Jefferson avenue) as shown in Fig. 2 of his paper, can hardly be advanced as an argument for concrete ties in railway track. The separate blocks (not connected by steel bars) are set upon and embedded in the concrete foundation of the street paving. The construction is simply a modification of the concrete foundation now often used for street railway track. It would seem to have been a less complicated construction to have left out the blocks and made a solid and continuous concrete foundation.

As to the cost and weight of the four ties noted, the figures given are apparently very inconsistent, due no doubt to the fact that they are not yet manufactured on a commercial basis. Mr. Kimball has a tie of 436 pounds, costing $1.30; Mr. Burbank has a tie of 250 pounds, costing $1.25, or almost the same as the 436-pound tie. Mr. Buhrer has a tie of 300 pounds, costing 90 cents; and Mr. Hickey has a tie of 500 pounds, costing $1.50.

Both Mr. Kimball's and Mr. Burbank's concrete ties have wooden blocks to carry the rails, serve as spiking blocks, and also give a certain elasticity to the rail support. But the use of these blocks presents some objections. In the first place, it is difficult to attach the wood so solidly to the concrete as to make a homogeneous structure (especially as renewal must be provided for) while the more the track can be built up as a homogeneous structure the better. In the second place, the use of wood blocks generally means the use of the old and inefficient spike. While there seems to be little prospect of the introduction of the improved rail fastening, it is certainly not desirable to provide for perpetuating the spike, (with its many defects) in new forms of ties which are intended to effect an improvement in track construction. In fact, one of the best features of the steel ties so largely and successfully employed in other countries is the efficiency and permanence of their rail fastenings.

As to affording elasticity: that is a feature that is not needed between the rail and tie. If the rails are securely and rigidly fastened to the tie, so that there is no pounding or hammering of the rail upon the tie, all the necessary elasticity or cushioning will be afforded by the ballast or roadbed. The only need of cushioning is to absorb shock. With wheels simply rolling on a stiff heavy rail with a perfectly level surface, the roadbed might as well be a solid mass of concrete or cast-iron. But the best of rails are not perfectly level, and with rail joints and locomotive hammer-blows to be considered there must be something to take up shock and vibration. This should be under the tie, however, and the rails and ties should be made to act as nearly as possible as a single structure. With this arrangement the best results in life wear of rails may be expected. Stephenson's trial of rails bolted to a rock bed are often mentioned, but his rails were light and the fastenings probably not very rigid. With 100-pound rails rigidly anchored to a dressed rock bed the results would probably have been very different, although the hammer-blow would still have to be cushioned.

It has sometimes been suggested that a continuous concrete floor should be laid for track carrying heavy traffic, as is frequently done for street railways, with rails resting directly upon the concrete. But the cost would be so great that it is hardly wort h considering such a plan from a practical point of view to-day. Another point is this: For street railway track, this construction is almost entirely used in built-up streets, where there is little chance for ordinary settlement or subsidence. On a railway, however, with shallow and deep cuts, high and low banks, and a variety of materials, there is always more or less settlement at various points, as well as heaving in winter. Such settlement, especially at the connection of a bank with a cut would probably result in cracking the concrete floor, admitting rain to soften the roadbed and aggravate the trouble. It would then be extremely difficult work to again build up the concrete roadbed to a true surface.

The concrete tie appears to possess certain advantages over the steel tie. In the first place, it has a greater bulk and weight, and there is no difficulty in obtaining sufficient weight for stability without reaching too high a cost. In the second place, the manufacture is much simpler and requires less expensive plant, even for manufacture on commercial basis. There is also less dependence upon market conditions than is the case with the steel tie. The use of concrete ties therefore is an interesting experiment, to be watched with interest, in view of future possibilities. But the experiment must be on a much larger scale and of much greater duration than at present before any such definite conclusions as are given in the paper can be drawn as to their practical efficiency or economy, and especially as to the efficiency or economy of any one particular form of tie.

In his conclusions as to the advantages of his tie the author mentions economy in fuel consumption, but I am afraid that is a very far fetched conclusion; such a result is uncertain, to say the least, and would be almost impossible to determine. Another advantage claimed is that it will not be necessary to break the bed below the tie; but this is not necessary with the wooden ties, the ballast between the ties (which carries no load) can be shoveled out, the tie knocked sideways from its bed and a new one slipped in without disturbing the bed itself. The shimming and adzing of wooden ties to maintain a perfect rail seat is commonly provided against to-day by the use of the metal tie-plates.

It is further claimed that widening of gauge due to bending of ties would be prevented. But his spikes in wooden blocks would not prevent the everyday trouble from widening of gauge due to the loosening of the spike and its being forced back into the wood.

The last conclusions, that with track once laid on concrete ties an arbitrary reduction of section force can be made, and that a large saving in maintenance-of-way charges can be expected, are, it seems to me, based on very little evidence. The results obtained with a few ties for a few years are insufficient basis for such conclusions. Mr. Kimball's ties and his experiments with them are of interest and value, in view of the present situation in regard to railway ties and track construction, but it is quite too soon to say that the tie is perfect or will prove generally satisfactory, and it is certainly too soon to say that it—or any other tie—will give such results in economy or efficiency as are claimed. The subject of substitutes for wooden ties is an interesting and important one, and Mr. Kimball's tie is one of many attempts to devise a successful substitute.

And finally I would repeat that the use of concrete ties is a promising proposition, and one that warrants consideration and experiment, but the concrete tie has got to prove itself by long and varied experience before it can be submitted to managers as a practical and well established improvement for track construction.

Mr. J. W. Schaub, M. W. S. E.—The scarcity of hard wood for ties will compel the railroads very soon to use softer woods. These will, no doubt, be creosoted and reinforced with tie-plates to carry the heavy loads they are now called upon to carry; but, after all, this will only be a makeshift. The real problem is, that with the present traffic a new form of roadbed will have to be developed. What this form of roadbed will be, the writer is not prepared to say, but the concrete tie, reinforced with steel will, no doubt, play an important part in its development. After the art of concrete-steel has reached a still higher stage of development, the cross-tie may perhaps be eliminated altogether, and a form of roadbed be evolved wherein the rail will rest directly on the roadbed, the latter being built of reinforced concrete, such as was outlined in *Engineering News* some four or five years ago.

However, what concerns the railroads to-day is to find a substitute for the timber tie, and the concrete-steel offers itself as the most likely substitute. The author has given a splendid start in this direction, which will no doubt in time bear good fruit. His criticisms of the unequal pressures developed under the cross-tie, in our present form or roadbed, are very striking; but, are not such conditions met with in all engineering structures; and, how are they met? Why, by simply providing for them. The writer, would suggest, that instead of eliminating the center bearing under the tie, by cutting the tie into two parts, as proposed by the author, that the tie be made strong enough to resist the bending produced by the eccentric loading. The question naturally arises, can a concrete tie be made strong enough? To this question the writer would answer, yes; and, moreover, from some experiments recently made on concrete-steel girders under train loads, the writer is convinced that the rail can be laid directly on the concrete-steel tie, without an intervening cushion of wood or otherwise. Moreover, the cross-section of the tie would be wedge-shaped or perhaps part of a cylinder; so that, when a tie is lifted out of its bed by the action of the rolling load, the ballast will run under the tie. Such a form of tie would require no tamping, in a gravel ballast. The rails would be held down by means of bolts with cast lug washers. These bolts would pass through gas pipes bedded in the concrete; so that in case a bolt is knocked off by a derailed wheel, or otherwise, the same can be easily replaced.

Assuming the present white oak tie to cost 60 cents, and its probable life to be ten years, the capital necessary, at 5 per cent interest, compounded, to renew this tie every ten years, will be $1.55. However, it is not at all likely that in the next ten years the tie can be renewed for any such sum as assumed; so that, it would be very conservative to say that we would, now, be justified in investing in any permanent form of tie to cost not to exceed $1.55. A concrete-steel tie, as previously described can be made for less than $1.40, so that a large margin is left for contingencies; to say nothing about the saving in maintenance of track, which would no doubt prove to be a large item. It would hardly be fair to carry the speculation any further. This question, of concrete-steel cross-ties can only be discussed intelligently after someone has been generous enough to invest in some experiments on different forms of ties.

and by no means should anyone be so rash as to run to the patent office every time a new form of tie has been thought of.

Mr. G. M. Mayer, M. W. S. E. (by letter)—It is a question of much importance, how to replace the wooden ties, heretofore used to such advantage, but now becoming more costly from the scarcity of timber. This question has also been before the railway companies of Europe, even longer than in this country. Experiments have been made with steel and cast-iron ties, if I am not mistaken, as long ago as 1880. With the ever increasing traffic on our railways, the establishment of more permanent structures is warranted, and is of material benefit in the long run. From this follows the inclination to make use of a more durable material than wood for cross-ties.

Steel-concrete construction having given satisfaction to such an extent, that factory buildings are now made of this material, including columns, floorbeams and rafters; it is very natural, that American as well as foreign inventors should have endeavored to use this same material for railway ties. I quite agree with a previous speaker, that it is not good business to protect by letters patent, every conceivable construction as soon as the "invention" is made on paper, and without giving the invention a practical test, for at least a brief period of time. The discussion of this subject by men in railway service, show a few failures of steel-concrete ties, and also some successes. No doubt, there have been many failures of which we did not hear. The concrete tie of Mr. Kimball, appears to have an advantage in the use of the wooden block, that comes from the electrical insulation provided by the block, as well as the cushion effect. On the other hand, the multiplicity of parts, as well as the raising of the rail above the roadbed are against the using of this tie. It is undoubtedly true that as long as use is made of steam locomotives, a certain elasticity under the wheels is required, as the balancing of the locomotive is based on an assumed maximum speed, and hence the moving parts are unbalanced at slower speeds or even higher speeds, than that assumed, which may occasionally occur. This imperfect balancing of the connecting rods, cranks, etc., produces blows on the rails to the detriment of them, the ties and their fastings. This difficulty does not exist with electric locomotives, or motor cars. In these machines there is a ring or drum armature in practically perfect balance, and working with a uniform torque in a magnetic field. Such machines would undoubtedly run on a track of solid concrete construction underneath the rails, which would only suffer at the joints, if butt joints are used. The experience of Mr. Buhrer with his solid steel-concrete tie, and without cushion blocks leads me to believe that with such tracks, the elasticity is provided by the soil underneath the ballast, or perhaps by a slight yielding of the tie in the bed.

Mr. T. Hickey, M. C. R. R.—I have had some experience with concrete ties. We first put some of these in a track in 1890, and they are still in the track. Since that time there has been a change in the manufacture of the ties, and I think with better results. The ties I first made were 8 feet long and the rail imbedded in the tie was 7 feet long, thus falling short 6 inches at each end of the tie. The rail was in about the center of the tie. I found that the track rails would cut into the concrete the same as they would in a wooden tie, although not quite so fast. I therefore used an iron tie-plate about ½-inch thick and 3 inches wide. In making the ties this tie-plate is embeded in the concrete. In order to fasten the rail to the tie I put in a piece of gas pipe about 1 ½-inch in diameter, and filled that with wood, which extended clear through the tie. My idea was that if the wood should decay, or be cut by spiking, it could be driven out and a fresh piece of wood put in. I found this wood plug would hold the spike fully as well as any wooden tie. The size of the pipe does not make much difference, but it would be well to have the gas pipe large enough to allow a change in the gauge to provide for any change in rails that might be made.

With the use of a tie-plate, the cutting of the rail into the concrete tie was entirely stopped, and we had no more trouble from it. Of the ties that are made in that manner—and some of them have been in service now for two years —I cannot see any signs of wear or deterioration. I do not know that I have entirely the right shape of plate for the tie, but I think something similar to what I have got is all right, and I am satisfied that a concrete tie carefully made in that way would give good service.

Mr. C Buhrer, L. S. & M. S. Ry—In Fig. 5 is shown a steel tie

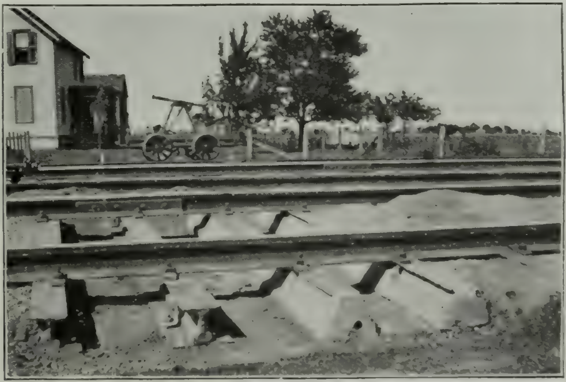

Fig. 5.

constructed out of an old rail. This was placed in the track on the Lake Shore & Michigan Southern Ry. on May 1, 1901. The illustration also shows concrete ties in the same track, each tie having a piece of rail along the top, embedded in the concrete. The latter, ties, were placed in track June 2d, 1902, and the photograph was taken in July, 1903. The ties are placed where trains go over them at the rate of 60 to 70 miles an hour, and there are perhaps 30 to 40 trains daily. The ties are just as good now as when they were placed; in fact, they are better—they are harder. The rail fastenings are bolts and clamps, and are much more rigid than any spike. The rail fastenings of the steel ties have been on two years up to last May, and are just the same as the day we placed them. The nuts were tightened ten days after the ties were put in the track and have not been touched since. I believe that the fastening is far superior to anything we have so far to hold our rails to the tie.

Fig. 6 represents a pile of ties, which were made early last spring, showing approximately the cross-section. These are made with a bevel underneath, so that in case a blow is struck with a tamping bar, the concrete will not be broken. We have found that if a blow is made with a pick, it glances off. This style makes a very nice, easy-tamping tie, and the section man has found that he can tamp that tie fully as well as a wooden tie.

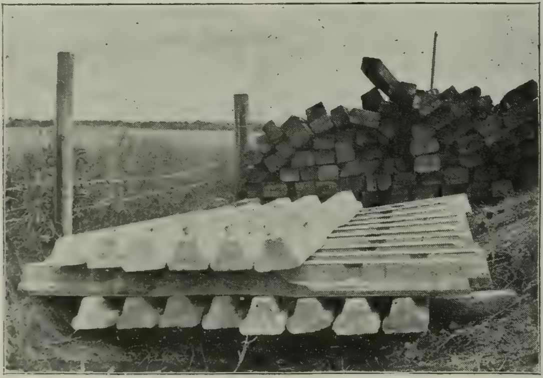

Fig. 6.

Fig. 7 represents a little change in the construction, the ends of the concrete being sloped off. We consider that rather a better way to make them, as we save a little concrete and have a nicer looking tie. There are 77 of these ties on the Ann Arbor Railroad on a 5-degree curve, where it is claimed the trains run from 60 to 70 miles an hour, and the track is much safer with these ties than with oak ties having tie-plates.

Fig. 8 represents a piece of track on a 12-degree curve on the Lakeside & Marblehead Ry. These ties were placed in the track July 6, 1903. The Superintendent, M. M. Harsh, has informed me that he is satisfied that he will maintain this piece of track for one-tenth its former cost when wooden ties were used. He states that this rail lays as perfectly to-day as the day it was laid, and that there is no sign of the rail moving. The photograph also shows that the wheels of the cars cover the entire surface of the rail head. I believe that in this construction we have done away with the rail

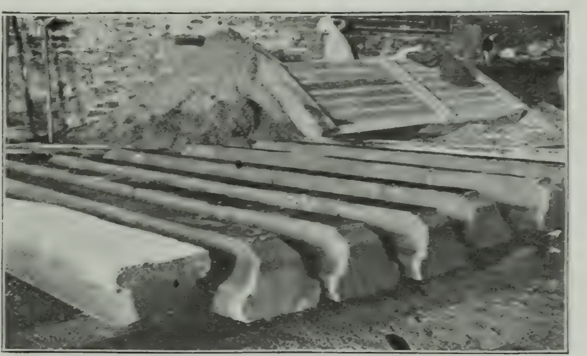

Fig. 7.

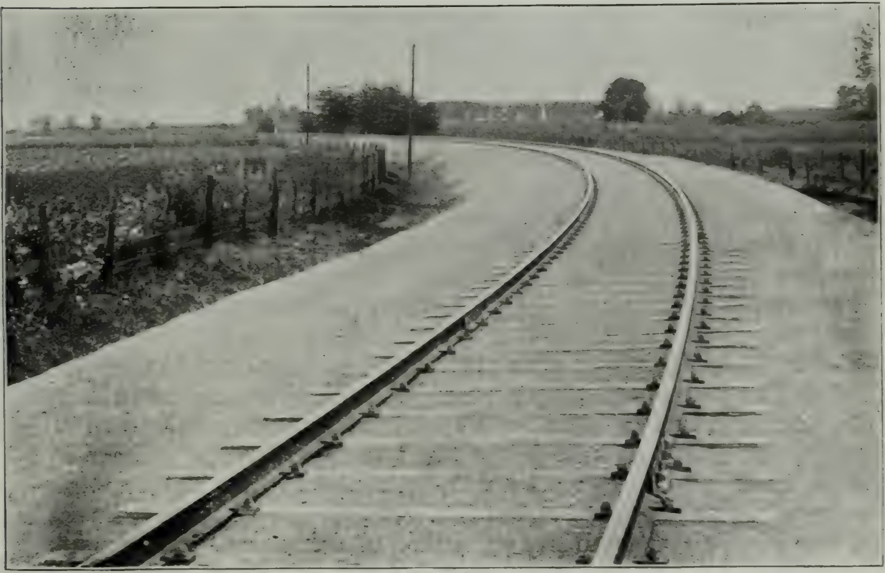

Fig. 8.

canting or cutting in on the sharp curves, and that we will get better service out of our rails than where they are allowed to cant and cut in the ties. There has not been one cent's worth of labor spent on the track since these ties were put in, although heavy engines run over it every day and it is on a 12-degree curve.

Fig. 9 represents the same curve on the north end, where you see there is a switch leading off the curve. In order to demonstrate that these ties could be used anywhere, we put them under the switch; we took away the slide plates, that we generally use on switches, and took away the braces. The stock rail is bolted to the ties as well as the main rail, and the switch slides on the ties. I consider this the most complete switch arrangement in this country to-day. No labor has been put on this track since it was put in. It is a caboose track switch and has very heavy use.

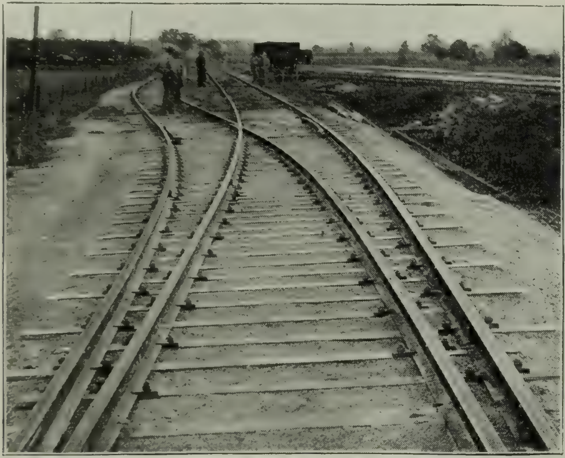

Fig. 9.

We now have this class of concrete tie on six different railways, and we have had no complaints where they have been used. The Pennsylvania Lines have 50 in the main track in stone ballast. It certainly looks as if these ties were all right.

Mr. W. M. Camp A little more than four years ago I had opportunity to see the beginning of an experiment with reinforced ties in this city, which I think was quite interesting, because that experiment turned out to be a failure; and to consider the manner in which the ties failed, is, I think, instructive. Mr. Tratman has touched on this experiment, but the Secretary has asked me tell what I saw of it, and also to say something of subsequent experiments with reinforced concrete ties.

Early in the spring of 1899 I was invited to go over on the west side, in this city, and see some reinforced concrete ties which were being made by Mr. J. J. Harrell. He was making them in a basement, a little distance west of the river, and I was requested to discuss the design of the tie and make suggestions.

This tie consisted of a body of concrete reinforced with a truss of 1-inch rods moulded in with the concrete. He had various designs which he thought of experimenting with, some being reinforced with two trusses side by side, but I believe the ties, for the main part, were reinforced with a single truss in each tie. There was a horizontal chord, then a small vertical strut at the middle of it, and the bottom chord sloped both ways to the bottom of that strut. These ties were 7 feet 4 inches long, and the cross-section of the tie was the shape of an inverted "U," with the sides somewhat sloping or flaring outward at the bottom. The bottom width of the ties at the ends was 10 inches, and the depth 8½ inches. The bearings for the rails might be called tie plates. They were steel plates about 4 inches wide, set in the concrete. The rail fastenings consisted of bolts and clips, the bolts anchored in the tie, being attached to the the ends of the reinforcing truss. If I remember correctly, they were U-bolts. I do not recall just how they were fastened to the truss—whether the "U" hooked under the truss or was fastened in some other way—but they were anchored about 1½ inches or 2 inches under the top face of the tie. I cannot give exact figures, because drawings were not given out, and at that time the gentleman did not desire to have the details published.

One thing I noticed in the construction of this tie, which is well to bear in mind in view of the outcome, was that his concrete was of a very dry mixture. He was tamping the concrete into the forms and brought no water to the surface. I discussed that matter with him and he seemed to think that if the material was thoroughly tamped the concrete would set properly and hold all right.

These ties were put into the track of the Pittsburg, Ft. Wayne & Chicago Ry., that summer, just a short distance south of the Union Station, where they had to carry very heavy traffic. Thirty of the ties were put under 85-pound rails, on a 6½-degree curve, in stone ballast, and occasionally I went over to see them. They had not been in the track long before two of the ties cracked across the middle, but the reinforcement held them together. They went through the next winter all right, and seemed to stand the frost in good shape, as far as the solidity of the concrete was concerned. But the trouble which eventually led to failure was with the fastenings. The rails began to spread on a tie at a time, and that spreading was due to the bolts working loose.

One defect, I think, in the bolts was their size—they were too small, being only 5/8-inch in diameter. It seemed that the flexure of the rail worked the bolts loose, and as the bolts loosened the rails began to pound the bearing plates, and failure was thus only a matter of course. The next spring they began to renew the concrete ties with wooden ones; that is, when the rails began to spread they would take out the defective concrete tie and put in a wooden one, and they continued this practice until all the concrete ties were removed. The larger part of them remained in the track a year and five months, but some were in two years.

Mr. Harrell was not discouraged with the results of this experiment. He thought that the main difficulty was with the rail fastenings and that he could improve on that feature of design. He accordingly set about making an improved design, and I think he was more successful. The next tie he made was reinforced with a steel web plate 7 inches deep and ¼-inch thick. This web was perforated with square holes, punched through, leaving at each hole a tongue of metal which was bent out at a right angle, to give the concrete a gripe on the plate.

The bearing for the rail in this case was a plate 5 inches wide riveted to the top of the steel web and coming at the top surface of the concrete. The position of the top edge of the steel web was about ½-inch under the top surface of the concrete, and the tie was 8⅝ inches deep. The length of the tie was 8 feet. The width of the the tie for about one-third of the length from each end was 9 inches on the bottom and 5 inches on the top, and at the middle the tie was contracted to a uniform width of 5 inches its whole depth. This diminished width over the middle third of the tie was also a feature of the previous design. He recognized the principle that the bearing surface of the tie should be decreased at the middle, so as to avoid centre binding of the track. The weight of this tie was 300 pounds, of which 55 pounds was metal.

He received quite a handsome order for these ties, but through some difficulty, after he had a company organized to manufacture them, they were never made. He did, however, make a few, which are now in a side track at Hegewisch, Ill., but of the results of that experiment I have not been informed. They were put in the track in 1901. It is interesting, if not instructive to note that this tie was made of a very wet mixture of concrete. The experience with the first type of tie caused Mr. Harrell to change his ideas entirely regarding the question of wet or dry concrete, with the result that he decided in favor of a wet mixture.

The next experiment with reinforced concrete ties which came to my attention was with Mr. Kimball's tie, of which you have heard tonight; and the next year Mr. Buhrer put some of his ties into the L. S. & M. S. Ry. track, as already explained by him. I have had the pleasure of seeing some of the latter ties in the track, in different places, and I must say that the appearance of the track is all that Mr. Buhrer has represented, I saw the 12-degree curve at Danbury laid with Buhrer ties. The track was in good surface and fine alignment, and appeared to be in excellent condition.

Mr. Buhrer makes a wet concrete, and his ties are as hard as flint. When they are unloaded they are thrown from the cars and fall upon the ground, in the same way that wooden ties are handled. Some of them were put into the Chicago & Northwestern road more than a year ago. They are in the track, opposite the platform, at the Allis Station, in Milwaukee, where some of you gentlemen may get a chance to look at them some time. The officials say they went through the winter all right, and thus far they think the experiment is promising.

Personally, I am pleased to see these experiments with concrete ties. So far as there has been opportunity to judge of the ties that have been in the track two and three years, there is no reason to think that they are going to fall to pieces very fast. In the Harrell ties the main body of the concrete remained intact, and there was no apparent disintegration or shattering from the blows of the train, other than has been explained in reference to the working of the fastenings.

There are some statements in Mr. Kimball's paper which are open to question, and he calls attention to some points which I think are well taken. For instance, he refers to the importance of weight and mass. That is a point that is quite commonly overlooked. I think the more weight you can get into the track the better it is. There is then less motion under traffic, and I think his recommendation in this respect is good.

Mr. Kimball seems to think the requirement that the tie should bear up under derailed wheels has been overlooked. I do not think it has been overlooked quite as much, perhaps, as some may think it has. I have heard this point discussed considerably with reference to the service of concrete ties. It is known that freight cars will sometimes become derailed and go several miles without materially injuring wooden ties. Of course if they ran over exposed concrete in that manner there would be serious injury. I think Mr. Buhrer took that point into consideration. He has, as you have learned, the base of a steel rail in the top of his concrete tie, which should afford protection against derailed cars.

As to Mr. Kimball's tie, I think the design is not so good in this particular. If a derailed wheel should strike the blocks which rest under the rail I am not so sure that they would stand against it. They might be split up or knocked out of place. I know that is the treatment that shims under the rails on bridge ties receive. A derailed wheel, if it cut into soft ballast in the middle of the tie, might strike the light channels and injure them.

A good feature of Mr. Kimball's tie is that it insulates the rails. If steel ties or concrete ties are to be used extensively, it is important to consider how the rails can be insulated, for automatic block signalling is being extended very rapidly on our railroads, and ties of the design like Mr. Buhrer's, and some others, would, for such service, have to be provided with some form of insulation. Mr. Buhrer, I believe, has experimented with insulation shims on top of his steel ties, and if any of the gentlemen present would like to learn more of these trials, I think Mr. Buhrer will be glad to speak about them.

In general, I think Mr. Kimball's criticisms are rather severe upon our present standards of track construction—in fact I think unnecessarily so. I do not think it necessary to point out some of the defects which he presumes to exist in order to find ground for the use of a tie of more permanent construction. He makes the statement that all track is center bound. I cannot agree with that opinion. Where track is imperfectly ballasted you will find that the condition he speaks of is prevalent to quite an extent, but where ballast is filled in as high as the tops of the ties, as far out as the ends and against the ends, and the track properly surfaced, I do not think you will find that center binding occurs to any considerable extent.

It is not true that in all cases track ties under traffic are depressed more at the ends than at the middle. Some years ago the maintenance of way department of the Warsaw-Vienna Ry. carried on an extensive series of experiments on the depression of track under traffic, and, among other things, the depression of the tie at various points in its length was recorded. Observations were taken with instruments of precision employing photographic apparatus, in which exposures were made by means of electric light reflected by means of mirrors, so that the effect of local disturbance of the ground surface was eliminated. These observations are pertinent in the present connection. The ties used were of oak, 6 in. deep, on gravel ballast 10 in. deep below the bottoms of the ties. With ties 8 ft. long the ends were depressed more than the center, but with ties 8 ft. 10 in. long the depression was greater at the center of the tie than at the ends.

From the data of these experiments, a tie about 8 ft. 6 in. long should undergo uniform depression throughout its whole length when under traffic. As 8 ft. 6 in. is the standard length of cross ties on a large number of roads in this country, and 9 ft. the standard length on a good many of the dirt-ballasted roads, with 6 to 7 in. the usual depth for ties, there is no good reason to suppose that under these conditions the tie should be depressed more at the ends than at the center, by the traffic, or that the tendency of things should be toward center-binding of the track. Such a tendency, as already explained, is dependent upon the manner in which the track is ballasted and filled in, and to some extent upon the length of the tie; but as the desirable conditions in these respects are within the limits of current railway practice, it is apparent that the tendency of track to center-bind is a matter which can readily be brought under control. In my estimation it is the least of the troubles which confront the trackmen of well-maintained railways.

He makes another statement which I consider quite extravagant; in fact, it quite surprises me. He thinks broken rails are seldom, if ever, caused by vertical pressure, but by lateral stress due to the bending of the ties across the middle of the roadbed. I cannot agree with this view at all. I do not think the bending of the ties, even at the maximum, has any appreciable effect in lateral stress on the rails. I do not wish to be understood, however, as criticising the paper unfavorably as a whole, but these few points, it seemed to me, should not pass unnoticed. I think the paper is timely, and I regard these experiments with reinforced concrete ties to be important and valuable at this time, when it seems that our supply of wooden ties is rapidly vanishing.

Mr. V. K. Hendricks, M. W. S. E.—I understood Mr. Schaub to say that it had been proved that the triangular tie would tamp itself. I would like to ask where and when that has been proved?

Mr. Schaub—I am not clear as to just where that was. As I understand it, the concrete tie is heavy enough so that it could not be lifted out of its bed. A concrete tie such as I described weighs over 600 pounds, and probably would not require any tamping on that account.

L. J. Mensch—I cannot say that I have had any experience in reinforced concrete ties, but I have to say that the success of these ties is well established.

There are nearly 1,000,000 concrete ties in use at present by the railroads in Indo-China. They have a very peculiar kind of ants which destroy wooden ties in a very short time, and therefore are forced to use steel or concrete ties.

These concrete ties are of an inverted T section, the flange of which is laid on the ground, and the stem is vertical. The rails are fastened by bolts which are imbedded in an enlargement of the stem where the rails pass.

They must be a success, because the company which manufactures them is establishing new offices in different parts of China. I know that the making of the tie is expensive, and costs in China for labor and centering 30 cents apiece, and the entire cost of the tie is probably $2. They are in use since five to six years, and are preferred to steel ties.

There is no doubt that concrete-steel ties are a success, and I think it possible to build them much cheaper, and we may look to the near future to see many railroads using concrete-steel ties.

Mr. H. S. Maddock. M. W. S. E. — In regard to a yielding surface, I judge that all the parties here present have believed it to be necessary. I was taught that; in the early days of railroading they put the rails on a solid foundation, but when you come to think of the manner of construction, I doubt if we today would consider the early roads laid on solid construction. I think you would find that some of the joints went down on one end and that we would get a rough track, and in listening to old men talk, who have ridden on those roads, I judge that was the case.

Now, the Street Railway Companies, to conform with the modern pavements, have been compelled to lay their rails on concrete, supported continuously. In some cases they lay them on concrete running parallel to the rail. In other cases it is solid concrete from one rail to the other. It has been used in Buffalo, Kansas City, Minneapolis, and a number of other cities. As far as I can learn it does not give a rough track and has not injured the rolling stock. The wheels roll on that track the same as on a cushioned track.

Is it not possible that on a road having a large traffic with a thoroughly compact roadbed we should lay our rails on a bed of concrete with the rails supported continuously, the same as described by some gentlemen in an article in the Engineering News some four or five years ago? That was the first time I had known of any such idea being expressed, and I thought the man was crazy, but since then I have been watching the matter. Take it here in Chicago, in our track elevation. We have a filling of sand, which gives good drainage, and for about four months of the year at least, we have a solid track. In the winter season we have just such a track as if those rails were laid on a bed of concrete.

Mr. W. E. Williams, M. W. S. E. — I would like to ask Mr. Chanute if he thinks the railway practice in the past, where they used the stone blocks and stone ties, was sufficiently thorough and complete to really prove the question of the yielding surface for the rail being required?

Mr. Chanute. — I remember seeing perhaps the last piece of stone block track that existed in this country on the Boston & Albany road. It was laid at East Albany with the old fish-bellied rail. It was on a side-track, and I remember that it was settled quite out of shape. It was evident that the frost had heaved the blocks, that such cars as still ran over that sidetrack had depressed it, and it was in very bad order. The books all state there was great difficulty with the rigidity of such track, and the book which has been quoted here tonight by Mr. Kimball, of Colburn & Holley, mentions an experiment, where, in order to secure an absolutely unyielding roadbed Mr. Stephenson dressed down the rock, or the rock was cut to a smooth surface, laid his rail thereon, and endeavored so far as he could to secure the equivalent of a lathe-bed, with the result that he found the track entirely unsatisfactory and took it up.

Mr. G. H. Paine—Since the question of continuously supported track has been raised it may be interesting for me to say that about a year ago I inspected a piece of track laid by the Metropolitan Street Railway as an experiment in New York City. The rail is continuously supported and imbedded in concrete. It is of the ordinary 80-pound street car pattern about 9 inches high with 5-inch base, and supports a heavy traffic of electric cars; yet the only bad places in that track were the joints, where the wheels had had a chance to pound the rail; otherwise, I think it was the most perfect track that I ever looked at and was a definite proof that a girder of sufficient depth will not break up the concrete. In reading Mr. Kimball's paper the only comment that I made was, that it contains no argument for concrete ties which does not apply more strongly to continuously supported track.

Mr. Schaub—I wish to say that the paper in the *Engineering News*, referred to by Mr. Maddock a few moments ago, was written by myself, and I am glad to have the support of such eminent authority. What I advocated at that time was not only a continuously supported track but a continuous rail. The rails were to be spliced by means of turned bolts, and the expansion joints were to occur about every 300 or 400 feet. The concrete roadbed, for a distance of 300 or 400 feet of track, was to be without any break. I realized the difficulty of supporting the ends of the rails, and that is why I specified that the rails should be continuous. These rail joints were not to be ordinary angle bar splices, but were to be special joints made by means of turned bolts. The expansion joints were to be scarfed joints, so that the rails would be really continuous as far as surface is concerned.

Mr. W. E. Williams—The conclusion which I would draw from what has been said here tonight would be, that the whole proposition rests in the statement which Mr. Chanute has made in regard to the cost of the tie per year, or for the period of time which the tie is in use, taking the first cost of the tie and interest. It would seem that from these figures the test is still in favor of the treated tie as to cost, unless you can show that you are going to produce a track so much superior, with your concrete ties, than is produced with the wooden tie, that the superior track is worth the extra cost. It appears to me that Mr. Buhrer's tie has offered the best solution of any that has been offered this evening. He gave no figures of cost that I noticed. I would like to know if that will figure out an approach to the cost which Mr. Chanute has made on the treated tie.

Mr. Buhrer—In the concrete ties I have so far constructed, I have used pieces of old 60-pound rails which weighed 140 pounds and also 165 pounds per tie. For the concrete I use a mixture of 1 in 4, composed of 2 parts of broken stone and 2 parts of gravel mixed with sand, and 1 part of cement. The majority of the ties were made by a mixture of 4 parts of gravel and 1 part of cement, and my experience is that a good, clean gravel makes the best and strongest concrete. It is possible to make nine ties out of one barrel of cement. At $2.00 a barrel for cement the cost per tie will be 20 cents, and about 3 cents for gravel used. I figure the labor in making and tamping that concrete at 15 cents, which brings the cost to 38 cents, exclusive of the value of scrap rail in the tie. However, with machine mixture and machine pressing, we could reduce these figures.

A concrete tie properly made ought to last 20 years. We have demonstrated that the concrete tie is safe, and we can expect a saving of 50 per cent in the course of 20 years, as compared with a wooden tie. I have not said anything in regard to maintaining a much more perfect track than we are able to maintain with wooden ties. This has been demonstrated so clearly that there is no doubt about it. The track has a much safer rail fastening, and requires less work.

Mr. Bainbridge, M. W. S. E.—I would like to call attention to the fact that a steam railroad differs in very important particulars from an electric street car line. The motive power on an electric street car line is entirely rotary, while on a steam railroad, you have the hammer action of the connecting rod as well as the impact of the counter-weight. While a rigid track might be the proper thing for an electric railroad, I am satisfied it would not be for a steam railroad. Where there is no elasticity to take up impact, the effect of a blow will crush anything. We get all variations, from perfect rigidity to perfect elasticity, and in a roadbed such as Mr. Chanute spoke of, on absolutely solid rock, I believe you will find the impact of the counterweight would crush a rail in a few days, or weeks at least.

Mr. Maddock—The counterweights, if they would pound the rails to pieces so quickly, why would they not do it when frozen in the winter time? We have just exactly such a track about four months in the year as you get with the rail on a continuous support of concrete.

Mr. Bainbridge—I would like to say that rails usually do break in the winter time.

Mr. Maddock—It is not the counterweight breaking them. Since Mr. Schaub's article came out I have been watching this thing. I was called on a few years ago to make an investigation in regard to a tie question. I went over the subject of metal ties, etc., and the conclusion I came to was—the next step in this country would be treating soft wood ties with a preservative and use tie plates, and then about that time this article came out, and I was satisfied, after looking over the condition of the track in the winter time, that eventually we would come to a continuous support on concrete, and it is not going to be a great many years before we shall all be convinced that we must have a solid track.

E. E. R. Tratman—There is one difficulty about the use of a continuous concrete foundation for railway track, as compared with street railways, as already explained. This construction is used almost entirely for electric railways in city streets, and it is not found in the open country. But in the streets the foundation or subgrade is protected and made substantial by the continuous line of buildings on each side, and by the sewerage and drainage systems, while it is further protected by the street paving. There are no slopes to wash and cause settlement. On a steam railway, however, the cuts and banks are exposed, and there is more or less of a continual settlement, washing, heaving, etc. A concrete bed on top of such a roadbed would probably very soon develop cracks, especially at the junction of cuts and banks, and when once broken and distorted it would be a difficult and expensive matter to again put the concrete bed in the solid and even condition which it is desired to maintain.

Mr. Bainbridge—In any event you have got to run your concrete below your frost line or you will not have any kind of success.

Mr. W. E. Williams—In regard to the theory of hammer blow upon the track, produced by the counter-balancing weight of the locomotive driving wheels, this was thoroughly treated, and I think exploded, in a paper at the World's Fair Congress of Engineers by an engineer, Mr. Barnes, who made locomotive construction his specialty. This paper will be found in our library, or certainly in the library of the Western Railway Club. I advise all hammer blow theorists to read it.

Mr. Maddock—I do not suppose the time will ever come when the continuous support and continuous rail is going to be very extensively used, except on lines having very heavy traffic, a thoroughly protected roadbed, and conditions of that kind. It may be possible that when we come to build a concrete base for our rails we may find, as we have already found in track elevation, when we are forced to use a concrete, we may find some way of making it cheaper than it is supposed it can now be done.

CLOSURE.

Mr. G. H. Kimball—In closing the discussion I wish first to say a word about the effect of hammer blow. In spite of what has just been said by Mr. Williams, hammer blow is a fact and not a theory. There was a recent case in my own experience where the passage of a single engine bent the rail, in the surface, for several miles, to such an extent that it was unsafe to run trains except at low speed. The rails were new and of 70-lb. standard section, but had to be taken out and re-rolled. I know of two other similar cases. These were all extreme cases, but as locomotives can only be counterbalanced for one speed, it follows that this force is present in some degree much of the time.

The question of cushioning naturally follows. With a tie of steel, or concrete and steel, we have an anvil, or series of anvils, under the rails. The result depends upon the relation of three factors — the inertia of the anvil, the shape and mass of the rail, and the force of the blows from the wheels of the passing trains.

In addition to the hammer blow we know that any vertical motion doubles, at least, the force of impact, and we cannot connect rails and ties so rigidly as to get a better effect than that would indicate.

In frozen roadbed, the fact that timber ties are still free to be depressed at their ends, provides a cushion in addition to the elasticity of the timber itself. I regard the cushion as absolutely essential, and it seems to me that failure on account of the destruction of the rails is otherwise a foregone conclusion.

Replying to Mr. Chanute, I have no disposition to minimize the real value of preservative processes for timber ties. So far as my information goes, the inferior qualities of timber have not been generally used. For some reason the roads seem to prefer the better qualities of timber. I have observed that preserved timber sometimes breaks across the grain with a fracture much like that of charcoal. However, my conclusion, "that the life of a tie is prolonged at a corresponding increase of cost," seems to be well sustained.

His statement concerning the effect of derailment needs modification, I think. The height of the rail cuts no figure in the effect on the tie produced by derailment, and I see no reason to anticipate unusual displacement while the wheels remain on the ties, as the base and height of the tie, including the cushion, are practically equal.

The amortization tables referred to are based on too high a rate of interest, and take no account of the cost of labor for tie renewals, nor of the economics introduced by permanent construction. They are therefore, as I think, misleading.

I omitted to state the number of ties put in track. Thirty-six have been put in, in most cases singly between timber ties. The first were put in in November, 1901, and the balance soon after, so that they have been in track nearly two years.

As to experience abroad, it seems to me that there is little with timber or with metal ties that can help us. Most conditions, particularly those concerning the weight and volume of traffic, are so unlike, that our own may be regarded as largely a special problem.

Mr. Camp's account of the Harrell tie is instructive. I note that the tie first broke in two at the center, permitting the ends to settle, and that it was then destroyed in detail at the fastenings.

I must take issue with him as to the question of track being center bound, in the sense that I have defined it. Ties are generally 8 feet long, and unless we can have timber ties 10 feet long, so that there is as much support outside of the rails as there is between the rails, or ties of concrete and steel stiff enough to carry their full length in the ballast without deflection, track will be center bound.

Both of these methods would seem to be prohibitive as to cost.

So far as my statements relating to the general condition of track on American roads are concerned, I maintain them without modification. There is a wide variation in degree, but the essential condition described prevails.

Remarks have been made by a number present favoring, in this connection, a better rail fastening than spikes. No effort has been made to revolutionize track construction, but on the contrary, I have tried to adapt my design to existing conditions. For the present at least, we must deal with spikes, which is a fastening not to be despised by any means. With permanent construction once adopted, better details for fastenings will follow, and they are readily adapted to any form of tie so far proposed.

As to the tie of a section like an inverted triangle, or of any section without a horizontal base, I do not see how it can succeed as there are forces other than the vertical to be dealt with. Those who maintain track know that in many cases it crowds longitudinally, and ties with an inclined base might be lifted off the bed.

Finally, I think it has been shown by the discussion that concrete ties will stand under railway traffic, and that we have only to deal with the question of design and cost. We may look for substantial results at no distant day.

To my mind the idea of a concrete track foundation for special purposes, and in special locations, does not seem at all visionary.

Where drainage is good, and track does not heave by frost, it can be applied without hesitation where the cost will justify. I believe that a six-inch course of good concrete, with ties spaced two feet on centre, will, in most localities, support the heaviest traffic.

CALCULATING COMPARATIVE COST.

[Written by B. E. Fernow.]

There appears to have been some difficulty experienced by engineers in coming to a conclusion as to how the cost of different systems, types, or processes ought to be compared, which vary as for instance in the case of ties in the initial cost, in the number of years that they will last, and, in addition, in the frequency at which the expense of renewal recurs. The difficulty, it seems, need not exist at all, and can be removed by the application of simple mathematical formulas and mathematical deductions, and put into a form which will allow a ready comparison.

The simplest and most satisfactory way of comparing two systems is by taking recourse to a calculation of annual charges.

The expenditure R occurring now and recurring every n years, like that for the renewal of railroad ties, is changed into an annual charge r by the formula.*

$$r = \mathrm{R}\,\frac{1.0\,p^{n}\;0.0\,p}{1.0\,p^{n}-1}$$

in which p is the rate of interest and $1.0\,p = \frac{100+p}{100}$

This formula is found by summing up the recurring intermittent expenditures (R) discounted to the present time on one side and setting them equal to the sum of the discounted annual charges (r) on the other side:

$$\mathrm{R} + \frac{\mathrm{R}}{1.0\,p^{n}} + \frac{\mathrm{R}}{1.0\,p^{2n}} \quad \cdot \quad \cdot \quad \cdot \quad = \frac{r}{1.0\,p} + \frac{r}{1.0\,p^{2}} + \quad \cdot \quad \cdot \quad \cdot \quad \frac{r}{1.0\,p^{n}}$$

In the following, Table I, the fraction $\frac{1.0\,p^{n}\;0.0\,p}{1.0\,p^{n}-1}$ has been computed for rate of interest at 5 per cent, and for various terms of n.

By multiplying the fraction, given for 1 cent expenditure, under the term in which the expenditure is to recur, with the actual amount of the expenditure in cents the annual charge is found.

This multiplication is carried out in the table for varying expenditures from 20 cents to 125 cents.

If a lower rate of interest is used in calculating the annual charges, these, to be sure, fall out lower, but the amounts of saving increase. So that it may be assumed that the table calculated upon a 5 per cent basis gives the most conservative, practically applicable results.

If the actual amount saved is to be determined, we need only find and compare the capitals which produce annually if placed on simple interest the amounts of the annual charge; or to arrive at the amount of that capital directly, we need only omit in the above formula the multiplication with $0.0\,p$.

In the above formula the charge is conceived to be made for the end of the year. Charging at the beginning of the year the formula is changed to $r = \frac{\mathrm{R}\,1.0\,p^{n-1}\,0.0\,p}{1.0\,p^{n}-1}$. To use the table for this formula it is only necessary to divide the figures with $1.0\,p$.

If the expenditure is not now incurred, but becomes first necessary after n years and then recurs at intervals of n years, like the cost of replacing railroad ties (assuming that the first laying is done at a different figure), or allowance for the value of the old material, the formula for the annual charge is changed into

$$r=\frac{\mathrm{R}\quad 0.0p}{1.0\,p^{n}-1}$$

For this the needful computations are found in Table II.

The above formula applies no matter whether the number of periods of renewed expenditure is taken as infinite or as a finite business term.

Another way of comparing two systems for a given business term is to calculate the total capital value of the recurring expenditures with compound interest for the given term; thus:

R=amount paid out once in n years.
m=number of terms of n years.
V=total capital value of the expenditures at the end of $m\ n$ years.
p =rate of interest; then

$$\mathrm{V}=\mathrm{R}\ \frac{(1.0\,p^{mn}-1)\ \ 1.0\,p^{n}}{1.0\,p^{n}-1}$$

If we consider two systems in which the corresponding values are $\mathrm{V}_{,}$, $\mathrm{R}_{,}$, $m_{,}$, $n_{,}$, and $\mathrm{V}_{,,}$, $\mathrm{R}_{,,}$, $m_{,,}$, $n_{,,}$, we have from (1)

$$\mathrm{V}_{,}=\frac{\mathrm{R}_{,}\ 1.0\,p^{n_{,}}\,(1.0\,p^{m_{,}n_{,}}-1)}{1.0\,p^{n_{,}}-1}$$

$$\mathrm{V}_{,,}=\frac{\mathrm{R}_{,,}\ 1.0\,p^{n_{,,}}\,(1.0\,p^{m_{,,}n_{,,}}-1)}{1.0\,p^{n_{,,}}-1}\qquad .\quad .\quad .\quad .\qquad (2)$$

Since for comparison we must have $m_{,}\ n_{,}=m_{,,}\ n_{,,}$, the values (2) give

$$\frac{\mathrm{V}_{,}}{\mathrm{V}_{,,}}=\frac{\mathrm{R}_{,}\ 1.0\,p^{n_{,,}}-1}{\mathrm{R}_{,,}\ 1.0\,p^{n_{,}}-1}\ 1.0\,p^{n_{,}-n_{,,}}$$

From this we see that the first or second system will be the more advantageous, according as $\frac{\mathrm{V}_{,}}{\mathrm{V}_{,,}}$ is less or greater than 1.

If, for instance, we introduce into these equations the following elements, in one case a tie costing 60 cents in the roadbed, lasting eight years, in the other case a tie costing the same but lasting sixteen years, 2,600 ties to the mile, we find for a term of thirty-two years, in the first case an expenditure of investment and accumulated interest of \$18,131.18, and in the other case of \$10,836.42, or, since

$$\frac{\mathrm{V}_{,,}}{\mathrm{V}_{,}}=\frac{2{,}600\times 60\times 1.05^{8}-1\times 1.05^{8}}{2{,}600\times 60\times 1.05^{16}-1}=0.60,$$

the saving of the longer-lived tie amounts to 40 per cent. By discounting the difference in accumulated expenditures after thirty-two years, namely, \$7,294.76 to the present year, according to formula $\mathrm{E}=\frac{\mathrm{A}}{1.0\,p^{n}}$, we get the present capital saving, namely, $1,531.90. This represents the financial advantage of the tie of longer duration for a thirty-two year run. For a longer run this amount increases naturally.

Example

Four systems are to be compared.

I. A metal tie system, requiring 2,000 ties per mile, the tie costing $2.40 to lay, lasting thirty-two years, and when taken out being worth 40 per cent of original cost or 80 cents.

II. A wooden tie system, requiring 2,700 ties per mile, the tie an oak tie costing 75 cents, to which 20 cents must be added for first laying and 15 cents for renewals, the tie lasting eight years, and when taken out being worth 10 per cent or 7.5 cents.

III. A wooden system of 3,000 ties, hemlock, ties costing 40 cents in the roadbed and lasting four years, without value when taken out.

IV. Hemlock tie system, with 2,700 ties, impregnated, at a cost of 20 cents per tie, and protected by a metal tie plate costing 30 cents per pair, and being worth 3 cents as old scrap at the end of twelve years, when the tie is taken out of service.

I. Metal tie:	
Annual charge on $2.40 for thirty-two years period	$15.12
Less annual charge for return of 80 cents after thirty-two years	1.04
	14.08
For 2,000 ties	281.60
II. Oak tie:	
Annual charge on 75+20=95 cents for eight years period	14.70
Add annual charge for renewals at 15 cents	.70
	15.40
Less annual charge for return of 7.5 cents every eight years	.68
	14.72
For 2,700 ties	397.44
III. Hemlock tie:	
Annual charge on 40 cents for period of four years	$11.28
For 3,000 ties	338.40
IV. Hemlock tie, treated, and with tie plate:	
Annual charge on 40+20+30=70 cents for period of twelve years	7.82
Less annual charge on return of 3 cents every twelve years	.19
	6.63
For 2,700 ties	206.00

Showing, as far as actual cost of the systems is concerned, outside of maintenance expenses, the treated hemlock tie, with tie plate, under the conditions assumed, the cheapest by from one to two-thirds, and the metal system next, but even at a cost of $2 per tie, 60 per cent cheaper than the oak.

AMORTIZATION TABLES.

TABLE I.—*For computing annual charge of initial expenditures.*

Expenditure	Term of years.																		
	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	16.	18.	20.	22.	24.	26.	28.	30.
	Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
1 cent	0.282	0.231	0.197	0.173	0.155	0.140	0.129	0.120	0.112	0.106	0.101	0.092	0.085	0.080	0.076	0.072	0.069	0.067	0.065
20 cents	5.64	4.62	3.94	3.45	3.10	2.81	2.59	2.40	2.24	2.13	2.02	1.84	1.71	1.60	1.52	1.45	1.39	1.34	1.30
25 cents	7.05	5.77	4.93	4.32	3.87	3.52	3.23	3.00	2.80	2.66	2.53	2.31	2.14	2.00	1.89	1.81	1.73	1.67	1.62
30 cents	8.46	6.93	5.91	5.18	4.64	4.22	3.89	3.61	3.38	3.19	3.03	2.76	2.56	2.40	2.27	2.17	2.08	2.01	1.95
35 cents	9.87	8.08	6.89	6.04	5.41	4.92	4.53	4.21	3.93	3.72	3.53	3.22	2.99	2.80	2.65	2.53	2.43	2.34	2.27
40 cents	11.28	9.23	7.88	6.90	6.19	5.62	5.18	4.81	4.49	4.25	4.04	3.69	3.42	3.20	3.03	2.89	2.78	2.68	2.60
45 cents	12.69	10.39	8.86	7.76	6.96	6.32	5.82	5.41	5.04	4.78	4.54	4.15	3.84	3.61	3.41	3.26	3.12	3.01	2.92
50 cents	14.10	11.54	9.85	8.63	7.74	7.03	6.47	6.01	5.60	*5.32	5.05	4.61	4.27	4.01	3.79	3.62	3.47	3.54	3.25
55 cents	15.51	12.70	10.84	9.49	8.51	7.73	7.12	6.61	6.15	5.85	5.55	5.07	4.70	4.41	4.17	3.98	3.82	3.68	3.57
60 cents	16.91	13.85	11.82	10.35	9.28	8.43	7.72	7.21	6.71	6.38	6.06	5.53	5.12	4.81	4.55	4.34	4.16	4.01	3.90
65 cents	18.32	15.00	12.81	11.22	10.06	9.14	8.41	7.81	7.26	6.91	6.56	5.99	5.55	5.21	5.93	4.70	4.51	4.35	4.22
70 cents	19.73	16.16	13.79	12.08	10.83	9.84	9.06	8.41	7.82	7.44	7.07	6.45	5.98	5.61	5.31	5.07	4.86	4.68	4.55
75 cents	21.14	17.31	14.78	12.94	11.61	10.51	9.71	9.01	8.37	7.98	7.57	6.91	6.41	6.01	5.69	5.43	5.21	5.02	4.87
80 cents	22.55	18.47	15.76	13.81	12.38	11.25	10.36	9.62	8.93	8.51	8.08	7.37	6.83	6.41	6.06	5.79	5.55	5.35	5.20
85 cents	23.96	19.62	16.75	14.67	13.15	11.95	11.00	10.22	9.48	9.04	8.58	7.83	7.26	6.81	6.44	6.15	5.90	5.69	5.12
90 cents	25.37	20.97	17.73	15.53	13.93	12.65	11.65	10.82	10.04	9.57	9.09	8.30	7.69	7.21	6.82	6.51	6.25	6.02	5.85
95 cents	26.78	21.93	18.72	16.39	14.70	13.35	12.30	11.42	10.59	10.10	9.59	8.76	8.12	7.62	7.20	6.89	6.59	6.36	6.17
100 cents	28.20	23.08	19.70	17.26	15.48	14.06	12.95	12.02	11.15	10.64	10.10	9.22	8.54	8.02	7.58	7.25	6.94	6.69	6.50
105 cents	29.61	24.24	20.69	18.12	16.25	14.76	13.59	12.62	11.70	11.17	10.60	9.68	8.97	8.42	7.96	7.61	7.29	7.03	6.82
110 cents	31.02	25.39	21.67	18.98	17.02	15.46	14.24	13.22	12.26	11.70	11.11	10.14	9.40	8.82	8.34	7.97	7.63	7.36	7.15
115 cents	32.43	26.54	22.66	19.85	17.80	16.17	14.89	13.82	12.81	12.23	11.61	10.60	9.82	9.22	8.72	8.38	7.98	7.70	7.47
120 cents	33.84	27.70	23.64	20.71	18.57	16.87	15.53	14.42	13.37	12.76	12.12	11.06	10.25	9.62	9.10	8.70	8.33	8.03	7.80
125 cents	35.26	28.85	24.63	21.57	19.35	17.57	16.18	15.02	13.92	13.30	12.62	11.52	20.68	10.02	9.48	9.06	8.68	8.37	8.12
Add for each additional 5 cts.	1.410	1.154	0.985	0.863	0.774	0.703	0.647	0.601	0.560	0.532	0.505	0.461	0.427	0.401	0.379	0.362	0.347	0.334	0.325

TABLE II.—*For computing annual charge of renewal.*

Expenditure.	Term of years.																		
	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	14.	16.	18.	20.	22.	24.	26.	28.	30.
	Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
1 cent	0.317	0.232	0.181	0.147	0.123	0.105	0.09	0.079	0.07	0.063	0.051	0.042	0.039	0.03	0.026	0.023	0.019	0.017	0.015
10 cents	3.17	2.32	1.81	1.47	1.23	1.05	0.90	0.79	0.70	0.63	0.51	0.42	0.39	0.30	0.26	0.23	0.19	0.17	0.15
12 cents	3.80	2.78	2.17	1.76	1.48	1.26	1.08	0.95	0.84	0.76	0.61	0.50	0.47	0.36	0.312	0.28	0.23	0.20	0.18
15 cents	4.76	3.48	2.72	2.21	1.85	1.58	1.35	1.19	1.05	0.95	0.77	0.63	0.59	0.45	0.39	0.35	0.29	0.26	0.24
20 cents	6.34	4.64	3.62	2.94	2.26	2.10	1.80	1.58	1.40	1.26	1.02	0.84	0.78	0.60	0.52	0.46	0.38	0.34	0.30

ABSTRACT OF THE MINUTES OF THE SOCIETY.

REGULAR MEETING—June 3, 1903.

A regular meeting of the Society (No. 500) was held in the Society Rooms the evening of Wednesday, June 3, 1903. The meeting was called to order at 8:20 P. M., with President Modjeski in the chair and about 55 members and guests present. The minutes of the meetings of May 5th and May 20th were read and approved. The Secretary reported from the Board of Direction the following as having been elected into membership of the Western Society of Engineers:

J. Milton Willard, Chicago, Active.
Earl C. Moss, Chicago, Active.
Malcolm F. Ewen, Chicago, Junior.
Felix Wm. Boldenweck, Chicago, Junior.
Peter Junkersfeld, Chicago, Active.
James E. Ferguson, Detroit, Mich., Active.
Walter W. Seymour, Chicago, Active.
Ralph S. McCormick, Detroit, Mich., Active.

The following new applications for membership had been received, and were referred to the Membership Committee in the usual course:

Leonardo Robertaccio, Chicago, Junior to Active.
Alfred Slade, Chicago, Active.
Chas. P. Christensen, Battle Creek, Mich., Junior.
Wilson P. Hunt, Moline, Ill., Junior to Active.
T. Frank Quilty, Chicago, Active.
Albert S. Crane, Chicago, Active.
Walter E. Dunham, Chicago, Active.

The Secretary also announced that the Board of Direction had accepted and approved the report from the Committee on the awarding of the three Octave Chanute medals for the best papers presented by members of the society during the year of 1902, as follows:

In Civil Engineering, Mr. John W. Alvord—"Sewage Purification Plants."

In Mechanical Engineering, Mr. Robert E. Milligan—"Mechanical Filtration."

In Electrical Engineering, Mr. E. B. Ellicott—"The Transmission of Fire Alarms."

On motion of Mr. Eldredge, this report was accepted by the Society.

On motion of Mr. Tratman, the meetings of the Society were suspended during the months of July and August.

President Modjeski announced the death of Mr. H. C. Draper, a member of the Society, on May 23d.

Mr. Tratman moved that the Chair appoint a committee of three to prepare a memorial of Mr. Draper, to be published in the Journal. The motion was duly carried.

There being no further business to come before the Society, Mr. Willard Beahan, of Winona, Minn., M. W. S. E., was introduced and presented a paper on "Railroad Reconnoissance."

Following this there was written discussion from Messrs. W. C. Armstrong and A. C. Schrader; and verbal discussion from Messsrs. Armstrong, G. S. Rice, A. S. Baldwin, Warder and Maddock.

The meeting adjourned about 10 o'clock.

EXTRA MEETING—June 24, 1903.

An extra meeting of the Society (No. 501) was held in the Society rooms Wednesday evening, June 24, 1903.

The meeting was called to order with Past President Chanute in the chair and about 55 members and guests present. No business was brought before the Society, and Past President Chanute introduced Mr. Wilber Wright, of Dayton, Ohio, who read a paper on "Experiments and Observations on Soaring Flight," which was illustrated by a number of lantern slides.

Discussion followed from Messrs. Chanute, Churchill, Bainbridge, Fox, Warder, Seddon, Wilson, Hermanns and Wilbur Wright.

The meeting adjourned about 10:15 P. M.

REGULAR MEETING—September 2, 1903.

A regular meeting (No. 502) of the Society was held Wednesday evening, September 2, 1903, with Mr. A. V. Powell, Past President, in the chair and about forty members and guests present.

The Secretary read the minutes for the meetings held June 3d and June 24th, which were approved.

The Secretary reported from the Board of Direction the election into membership in the Society of the following persons:

At their meeting June 30, 1903,

Joseph D. Smedberg, Joliet, Ill., Junior.
Alfred Slade, Chicago, Active.
Wilson P. Hunt, Moline, Ill., Junior to Active.
Albert S. Crane, Chicago, Active.

The following applications had been received and referred to the Membership Committee in the usual course:

Robert B. H. Begg, Chicago, Junior.
Wm. Carroll, Chicago, Active
Chas. A Amari, Chicago, Junior.
Robert F. Massa, Chicago, Active.
Chas. F. Drake, Chicago, Active.
Elwood N. Layfield, Chicago, Active.
Frederick C. Austin, Chicago, Associate.
Herbert Milker, Chicago, Associate.

Also at the meeting August 4, 1903, of the Board of Direction, the following persons were elected into membership.

T. Frank Quilty, Chicago, Active.
Walter E. Dunham, Chicago, Active.
Robert B. H. Begg, Chicago, Junior.
Chas. A. Amari, Chicago, Junior.
Chas. F. Drake, Chicago, Active.
Elwood N. Layfield, Chicago, Active.
Herbert Milker, Chicago, Associate.

The following applications had been received and referred to the Membership Committee in the usual course:

Frank E. Rainier, Chicago, Active.
John G. Kreer, Chicago, Active.
John G. Spielman, Chicago, Active.
Chas. H. Dow, Jr., So. Kaukauna, Wis., Junior.

Also at the meeting of the Board of Direction, September 1, 1903, the following persons were elected into membership:

Frank E. Rainier, Chicago, Associate.
John G. Kreer, Chicago, Active.
John G. Spielman, Chicago, Active.

The following applications were received and referred to the Membership Committee in the usual course:

Jay Arthur Rossiter, Chicago, Junior.
F. W. L. Humphrey, Chicago, Junior.
C. H. Hettelsater, Oak Park, Ill., Active.
F. C. Rossiter, Chicago, Active.

The Secretary announced the death of Mr. Geo. S. Morison, M. W. S. E., July 1, 1903, and on motion of Mr. Finley, duly seconded and carried, that the Chair appoint a committee to prepare a suitable memorial of Mr. Morison, the Chair, Mr. Powell, stated that he would appoint on that committee Messrs. Chanue, Parkhurst, Corthell, Noble, Modjeski and Gerber.

The Chair also announced that Mr. G. W. Jackson, M. W. S. E., had invited the members of the Society and their friends to inspect the new telephone exchange and telephone tunnels lately built under the streets of Chicago. This invitation had already been sent out by card.

The Chair announced the paper for the evening—"The Development of the Coal and Coke Industry of the Colorado Fuel and Iron Co.," by Mr. L. B. Merriam, M. W. S. E., which, in the absence of the author, was read by the Secretary. Discussion followed from Messrs. Finley, Karner, Powell and Warder.

The meeting adjourned about 9 P. M.

EXTRA MEETING—September 16, 1903.

An extra meeting of the Society (No. 503) was held in their rooms Wednesday, September 16, 1903, with President Modjeski in the chair and about 60 members and guests present.

The meeting was called to order about 8:20 P. M. No business was brought before the Society, but Mr. G. H. Kimball, of New York, was introduced, who presented a paper on "The Tie Problem. With Special Reference to Concrete Ties," which had previously been printed and sent out to the members.

Written discussion was presented at the conclusion of the reading of the paper, from Messrs. Dawley, W. W. Curtis, Chanute, H. H. Ross, Tratman, Schaub and Geo. M. Mayer, and oral discussion followed from Messrs. T. Hickey (M. C. R. R.), C. Buhrer (L. S. & M. S. Ry.), W. M. Camp, Hendricks, Schaub, L. J. Mensch, Maddock, W. E. Williams, Chanute, G. H. Paine, Bainbridge and Tratman, with a closure by Mr. Kimball.

The meeting adjourned at 10:40.

EXTRA MEETING—September 30, 1903.

An extra meeting of the Society (No. 504) was held in their rooms Wednesday evening September 30, 1903, with Vice-President Parkhurst in the chair and about fifty-five members and guests present.

The meeting was called to order about 8:30 P. M. No business was brought before the Society, but Mr. T. T. Johnson, M. W. S. E., presented a paper on "Hydro-electric Power Development at Joliet, Ill." The paper was illustrated by lantern slides and also a map showing the geography and topography of the district, with the proposed plans.

At the conclusion of the reading of the paper, a motion was made by Mr. Seddon, and duly carried, that the paper be printed and sent out to the members as promptly as may be, so that opportunity may be given for discussion at some subsequent meeting, before the printing of the paper in the Journal of the Society.

The meeting adjourned at 10:30.

REGULAR MEETING—October 7, 1903.

A regular meeting of the Society (No. 505) was held in their rooms October 7, 1903, with Vice-President Parkhurst in the chair and about sixty members and guests present. The meeting was called to order at about 8:15 P. M.

The Secretary read the minutes of the meetings held September 2d, September 16th and September 30th, which were approved.

The Secretary reported, on behalf of the Board of Direction, the election of the following persons into membership of the Society, at their meeting held October 6th:

Frederick C. Austin, Chicago, Associate.
Chas. H. Dow, Jr., So. Kaukauna, Wis., Junior.
J. A. Rossiter, Chicago, Junior.
F. W. L. Humphrey, Chicago, Junior.
C. H. Hettelsater, Chicago, Active.
F. C. Rossiter, Chicago, Active.

The following new applications had been received and referred to the Membership Committee in their usual course:

Ernest McCullough, Marshfield, Wis., Active.
Frank A. Windes, Winnetka, Ill., Active.
Valentine I. Smart, Chicago, Junior.
Oscar Seaberg, Chicago, Active.
Wm. Krames, Kansas City, Kan., Active.
Chas. E. Sargent, Chicago, Active.
N. P. Frandsen, Chicago, Active.

The Secretary presented a petition for amendment to the Constitution, for the purpose of increasing the Board of Direction, signed by more than the requisite number of ten active members of the Society, the amendment to read as follows:

"ARTICLE IV.

"OFFICERS.

"SEC. 1. The officers of the Society shall be a President, three Vice-Presidents, a Secretary, a Treasurer, and three Trustees. The above named officers, except the Secretary, together with the last three past Presidents, who continue to be members, shall constitute a Board of Direction, in which the government of the Society shall be vested."

The object of this amendment was explained quite fully by the Secretary. He also explained that in case the amendment was adopted, some slight modifications of the By-laws would be necessary, the following draft of which was submitted:

"To Article II, Section 1, add the words 'Third Vice President' after the words 'Second Vice President,' so that the paragraph will read:

"'Section 1. The President, Vice President, Second Vice President, Third Vice President, and Treasurer,' etc., etc.

"To Article III, Section 2, fourth paragraph, at top of page 8, introduce after the words 'Board of Direction' the words 'except the past Presidents,' so that the paragraph will read:

"'Any member of the Board of Direction, except the past Presidents, who shall absent himself,' etc., etc."

After the presentation of this matter of amendments, there was some general discussion among members present.

The chair then announced the paper for the evening—"Sewage Disposal in Iowa," by Prof. A. Marston. The paper was illustrated by numerous lantern slides, and was discussed by Messrs. Parkhurst, Finley, Randolph, Shnable, Poetsch, A. J. Cox, Burdick and Marston.

The meeting adjourned at 10 o'clock.

EXTRA MEETING—October 21, 1903.

An extra meeting of the Society (No. 507), was held in their rooms October 21, 1903, with President Modjeski in the chair and about 75 members and guests present.

The Secretary announced that there would be an excursion for the benefit of the members of the society and their families, to Thebes and Carbondale, Ill., leaving Chicago Thursday evening, October 29th, and returning by Saturday noon, October 31st.

As there was no business to come before the society, the President introduced Mr. G. A. M. Liljencrantz, who presented his paper on "The Haskell Self-Registering Water Gauge," which was illustrated by lantern slides.

Some discussion followed the presentation of this paper, from Messrs. Benezette Williams, T. T. Johnston, Seddon, Warder, L. E. Cooley, Isham Randolph, Shnable and Liljencrantz.

Following this, discussion was offered on the paper by Mr. T. T. Johnston, read September 30th, on "The Hydro-Electric Power Development at Joliet, Ill.," from Messrs. Randolph, Wisner, Johnston, Benezette Williams and Seddon.

On motion of Mr. Cooley, further discussion was deferred until some subsequent meeting to be set by the Board of Direction.

Meeting adjourned at 10:55 P. M. J. H. WARDER, Secretary.

REPORT OF THE ENTERTAINMENT COMMITTEE.

A called meeting of the Society (No. 506) was held Saturday evening, October 17, 1903. This meeting was "Ladies' Night," and those present, about 175 ladies and gentlemen, were entertained with an illustrated lecture from Mr. W. J. Karner, M. W. S. E., "Across the North Sea to Holland." The meeting was held in Kimball Hall, No. 243 Wabash avenue, as our own rooms were not large enough to accommodate those who desired to be present.

In the absence of President Modjeski, the meeting was called to order by Past President Randolph, who, in a few graceful and happy sentences, introduced Mr. Karner, and also stated that the speaker would soon leave Chicago to engage in business in New York.

The lecture was illustrated by many beautiful lantern slide views of London and Holland.

At the conclusion of the lecture refreshments were served.

W. H. BALDWIN, Chairman.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the issue of the JOURNAL for June, 1903, we have the pleasure to report the following gifts from donors named:

BOOKS PURCHASED.

Federated Institution of Mining Engineers, Newcastle-upon-tyne, Vols. 1 to 7 inclusive, 1889-1894.

MISCELLANEOUS GIFTS.

E. B. Ellicott, City Electrician, M. W. S. E:
"Annual Report, 1900, Board of Examiners of Operators of Automobiles, Chicago." Pamphlet.
"Municipal Affairs." Vol. VI. No. 4, "Municipal Operations and Public Franchises, Winter 1902-3."
Department of Electricity, Chicago, three books, cloth, Annual Reports, 1900-1901 and 1902.
J. Willard Morgan, Comptroller, State of New Jersey, one book, cloth, Railroad and Canal Reports, 1902.
State Board of Health, South Carolina, pamphlet, 23d Annual Report, 1902.
" " " " Michigan, one book, cloth, 29th " " 1901.
" " " " New Jersey, one book, cloth, 26th " " 1902.
Burlington, Vt., Report of Health Officer, Jan., 1903. Pamphlet.
British Association of Waterworks Engineers, one book, cloth, Vol. VII, Transactions for 1902.
Iowa Railroad Commissioners, one book, cloth, 25th Annual Report, 1902.
Lowell, Massachusetts, Water Board, pamphlet, 30th Annual Report, 1902.
Walter Loring Webb, one book, morocco, "Railroad Construction,' 1903.
John Brunner, M. W. S. E., Chicago, five pamphlets,
Report Sewerage Commission, Baltimore, 1897.
" Commissioners of Accounts, New York City, "Notes on Cement Testing," May 20, 1901.
"Asphalt Paving," May 9, 1899.
Nature and Origin of Asphalt, by Clifford Richardson, October, 1898, Long Island City.
U. S. Dept. of Agriculture, Bureau of Forestry, "Seasoning of Timber," by von Schrenk. 1903.
D. Van Nostrand Co., New York City, "Traverse Table." 1903. Cloth.
" " "Flexure of Beams," by Albert E. Guy.
Engineering News Publishing Co., New York City, one book, cloth, "Earthwork and its Cost," by H. P. Gillette, 1903.
McGraw Publishing Co., New York, one book, cloth, "The Alternating Current Transformer," by F. G. Baum, 1903.
S. Whinery, New York City, one book, cloth, "Municipal Public Works." 1903.
Geo. G. Earl, Gen'l Supt. Sewerage and Water Board, New Orleans, one book, cloth, "Report on Water Purification Investigations," etc. Jan., 1903.
E. E. R. Tratman, M. W. S. E.:
"Municipal Ownership in England," 1902. Pamphlet.
"Seventeenth Annual Report (1902) Illinois Society of Engineers and Surveyors." Pamphlet.
Eight cloth bound volumes, as follows:
"Les Dirigeables," by M. H. André.
"La Navigation Sous-Marine," by Maurice Gaget.
"Traité Pratique des Machines Marines Motrices," Vols. I and II, by J. B. Girard.
"Massachusetts R. R. Commissioners' Report," 1901.
"Report of R. R. and W. Commission, Ill., 1901.
"Street Railways of Chicago," Report of City Council, 1898.
"Taylor Signal Co., Buffalo, 'Electric-Interlocking System.'"

"Proceedings, 8th and 9th Conventions, Air Brake Association," 1901-2.

Four pamphlets:

"Railway Signalling Club Proceedings," 1902.

"Twelfth Annual Convention, Association Railway Superintendents of Bridges and Buildings, 1902."

"The Wisconsin Engineer," January, 1889.

"Examination Questions and Answers on the Air Brake. 1901."

Prof. B. E. Fernow, New York State College of Forestry, "Lectures on Forestry," 1903, by Fernow.

American Iron and Steel Association, Philadelphia, pamphlet, "Statistics of the American and Foreign Iron Trades for 1902."

Wm. Wallace Christie, Paterson, N. J., one book, cloth, "Furnace Draft, its Production by Mechanical Methods," 1901.

Frederick L. Ford, City Engineer, Hartford, Conn , pamphlet, "Hartford Municipal Information."

Harper & Bros., one book, cloth, "The Rise and Progress of the Standard Oil Co.," by G. H. Montague.

J. B. Henderson, Brisbane, Queensland Australia, Reports Hydraulic Engineer, Water Supply Dept., 1894-6.

Massachusetts State Board of Health, Report on the Charles River Dam, etc., 1903.

BOOKS FROM THE ESTATE OF JAMES MAC ARTHUR.

Van Nostrand's Eclectic Magazine, 32 volumes.
Bulletin du Canal Interoceanique, 3 volumes.
Submarine Blasting in Boston Harbor. Foster.
Kansas City Bridge. Chanute.
The Forth Bridge.
Lowell Hydraulic Experiments. Francis.
Report on Mississippi River. Humphreys & Abbott.
Applied Mechanics. Rankine.
Manual of Civil Engineering. Rankine.
Narrow Gauge Railways in America. Fleming.
Iron Highway Bridges. Boller.
Jackson's Optics.
Treatise on the Resistance of Materials. Wood.
Mechanics of Engineering and of the Construction of Machines. Weisbach.
Ure's Dictionary of Arts, Manufactures and Mines, 3 volumes.
Specimen Bridges, United States Railroads. Duggan.
American and European Railway Practice. Holley.
Brooklyn Water Works and Sewers. Van Nostrand.
Shortrede's Logarithmic Tables.
Tri-nitroglycerine. Mobray.
Theory of Strains. Stoney. 2 volumes.
Gillespie's Land Surveying.
Rudiments of Hydraulic Engineering. Burnell.
Trautwine on Railroad Curves.
Street Railways. Easton.
Scribner's Ready Reckoner.
Draughtsman's Alphabets. Keuffel & Esser.
Oblique Bridges. Buck.
Smyth's Treatise on Algebra.
Moseley's Mechanics of Engineering.
Military Bridges. Haupt.
A New Manual of Logarithms. Bruhns.
Synthetic Mechanics. Bartlett.
Philosophy of Mathematics. Gillespie.
Method of Least Squares. Wm. Chauvenet.
Bow on Bracing.
Skeleton Structures applicable to Steel and Iron Bridges. Henrici.
Pratt's Cubic and Biquadratic Equations.

Plane and Spherical Trigonometry. Peirce.
Todhunter's Theory of Equations.
Elementary Linear Perspective. Warren.
Roadmaster's Assistant. Huntington.
Smyth's Analytic Geometry.
D'Aubuissons' Hydraulics. Bennett.
Todhunter's Algebra.
Elements of Mechanics. Peck.
Peck's Books of Science. Barrie.
Mathematical Theory of the Steam Engine. Baker.
Long Span Railway Bridges. Baker.
Locomotive Engine. Colburn.
Economic Theory of the location of Railways. Wellington.
Smyth's Calculus.
Tubular and other Iron Girder Bridges. Dempsey.
American Engineers' and Surveyors' Instruments. Gurley.
Engineers' and Mechanics' Pocket Book. Haswell.
Handbook of the Steam Engine. Bourne.
Catechism of the Steam Engine. Bourne.
Laws and Regulations of the Engineering Department of New York.
Strength of Materials. Whilden.
Loomis' Algebra.
Mechanics. Byrne.
Iron Bridges and Roofs. Unwin.
Smyth's Mechanics.
Geological Survey of Indiana, 1870. Cox.
Jackson's Mechanics.
Manual for Railroad Engineers, with text and plates. Vose.
Davies' Bourdon—Elements of Algebra.
Mechanism and Machinery of Transmission. Fairbairn.
Ray's Series, Analytic Geometry, by Howison.
Roads and Railroads. Gillespie.
Analytical Mechanics. Bartlett.
Practical Treatise on Bridge Building. Whipple.
Boileau's Traverse Tables.
Haupt on Bridge Construction.
Formulæ for Constructing Railroads. Borden.
Treatise on the Construction of Bridges and Roofs. Wood.
Industrial Drawings. Mahan.
Young's Differential Calculus.
On the Strength of Cast Iron Pillars. Francis.
On the Strength of Beams, Columns and Arches. Baker.
Chamber's Mathematical Tables.
Neville's Hydraulic Formulæ.
Baldwin Locomotive Works. Trade Catalogue.
Iron Railway Bridge Across the Mississippi River at Quincy, Illinois. Clarke.
Water Works for Supply of Cities and Towns. Hughes.
Gas Works. Hughes.
Drainage and Sewage of Towns and Buildings. Dempsey.
Masonry and Stone Cutting. Dobson.
Railway Masonry and Bridge Foundations. Hasley.
Strains in Girders. Humber.
Mechanics' Companion. Scribner.
Inventor's Guide. Moore.
Copp's Handbook of Mining Law.
Geological and Geographical Atlas of Colorado. Hayden.

PAMPHLETS.

Resources and Natural Wealth of Arizona. Hinton.
History of the Sault Ste. Marie Canal. Kelton.
California State Mineralogist Report for Sept. 15, 1892.
International Deep Waterways Association—proceedings.

Engineering News, 470 copies.
Engineering and Mining Journal, 132 copies.
Railway Review, 37 copies.
Engineering Record, 15 copies.
Inland Architect, 14 copies.
Railroad Gazette, 4 copies.
Sundry other papers, 6 copies.

BOOKS FROM C. L. GOULD.

Dodd—Dictionary of Manufactures.
Brown—507 Mechanical Movements.
Weisbach—Mechanics of Engineering.
Gillespie—Philosophy of Mechanics.
Rankine—Civil Engineering.
" Applied Mechanics.
The Forth Bridge.

BOOKS AND PAMPHLETS FROM J. H. WARDER, SECRETARY.

Geological Reports: Michigan, 1838.
New York, 1838 and 1840.
Delaware and Jersey, 1841.
Pennsylvania, 1838.
Virginia, 1836.
Agriculture and Geology of Maine, 1861.
Dictionary of Geology and Mineralogy, by Wm. Humble.
New Water Works, Detroit, Michigan.
Smithsonian Reports, 11 volumes.
Machinery and Mill Work. Rankine.
The Steam Engine. Rankine.
A Treatise on Hydraulics,by D'Aubuisson De Voisins.
General Problems of Shades and Shadows. S. Edward Warren.
The Railway Engine Driver's Guide.
Construction, Heating and Ventilation of Hot Houses. Leuchars.
Turning and Mechanical Manipulation, by Holtzapffel. Volumes I, II and III.
Shades and Shadows. Davies.
Treatise on Astronomy. Herschel.
Rudimentary Treatise on Locomotives. Dempsey.
Drafting Instruments and Operations. S. Edward Warren.
Elementary Geometrical Drawing. S. Edward Warren.
A Treatise on Arithmetic. James S. Eaton.
Analytical Geometry. Church.
Statistics of Coal. Richard Cowling Taylor.
Problems in Stone Cutting. S. Edward Warren.
Coal, Iron and Oil. Daddow & Bannan.
Business Album of the Michigan Bridge Construction Co., Detroit.
Electric Light Installations. Salomons.
Transformers. C. D. Haskins.
A Treatise on Cranes. H. R. Towne.
Designing and Construction of Machine Gearing. Joynson.
Handbook of the Steam Engine. Bourne.
Catechism of the Steam Engine. Bourne.
Principles and Practice of Levelling. F. W. Simms.
Steam Making or Boiler Practice. Prof. C. A. Smith.
Hewson's Principles and Practice of Leveling.
Tables of the Properties of Saturated Steam. Peabody.
Free Hand Geometrical Drawing. Warren.
Testing Water Wheels. James Emerson.
Manual of Mineralogy. James D. Dana.
Elements of Railroading. Chas. Paine.
Practical Use of the Blowpipe.
London Engineering, 10 volumes bound, 10 volumes unbound, 5 odd copies.
The Steam Engine. Tredgold.

Illustrations of Steam Machinery and Steam Naval Architecture. Tredgold.
The Practical Draughtsman. Johnson.
The Modern Builder's Guide. Lafever.
Atlas of Engravings for "Locomotive Engine." Dempsey.
Illustrations to the Geological Report of Wisconsin, Iowa and Minnesota. Owen.
Engineer and Machinist's Drawing-Book.
Lands of the Arid Region. Powell.
Construction of the Turbine. Cullen.
Board of Water Commissioners, Detroit, Mich., 1885.
Report, New York, Providence & Boston R. R. Co., 1886.
Reports, Cincinnati Southern Ry., 8 pamphlets.
" Cincinnati, New Orleans & Texas Pacific Ry. Co., 2 pamphlets.
Vicksburg & Meridian R. R. Co.
Department of Public Works, Chicago, 1874-1876.
"Manufactures and Builders," 28 numbers.
"Scientific American" and supplement—1 vol. each.

EXCHANGES.

Society of Engineers, London, cloth bound volume, Transactions, 1902.
Iron Age Directory, 1903.
R. R. Commissioners' Report, Mass., 1903, cloth.
Interstate Commerce Commission, Washington, 16th Annual Report, December, 1902. Cloth.
Michigan Technic, Vol. XVI, 1903. Pamphlet.
Lake Superior Mining Institute, Proceedings, August, 1902. Vol. VIII. Pamphlet.
American Society Heating & Ventilating Engineers, one cloth bound volume. Transactions, 8th annual meeting, 1902.
New Jersey State Board of Health, one book, boards, "Report, Vital Statistics, 1901."
Royal Engineers' Institute, "Professional Papers for 1902." Cloth.
Wisconsin Survey, Bulletin IX, "Lead and Zinc Deposits," by U. S. Grant, 1903.
Wisconsin Survey, Bulletin X "Highway Construction in Wisconsin," by E. R. Buckley. Cloth. 1903.
American Electrochemical Society, New York, Transactions, 1903.
Sanitary District of Chicago, Annual Report of the Engineering Department, 1902. Pamphlet.
W. C. Simmons, Providence, R. I., Annual Report of Commissioner of Dams and Reservoirs, R. I. Pamphlet.
Lawrence, Mass., Water Board, Annual Report to City Council, 1902. Pamphlet.

GOVERNMENT PUBLICATIONS.

U. S. Dept. of Agriculture, Bureau of Forestry, pamphlets.
"The Woodlot." Graves and Fisher, 1903.
"Tests on Physical Properties of Timber," by F. E. Olmstead.
"Influence of Forestry upon the Lumber Industry," by Price.
"Practicability of Forest Planting in the United States," by W. L. Hall.
"Forestry and the Lumber Supply."
"The Forests of Oregon," by Henry Gannett, 1902.
"The Forests of Washington; a Revision of Estimates," by Henry Gannett.
"Forest Conditions in the Cascade Range, Washington," 1902 by Plummer.
"Forest Conditions in the Olympic Forest Reserve, Washington," by A. Dodwell.
"Forest Conditions in the Northern Sierra Nevada, California," by J. B. Leiberg.
"Forest Conditions in the Cascade Range Forest Reserve, Oregon," 1902.
U. S. Geological Survey, Dept. of the Interior:
Volumes, 42, 43, 44, 1901, 1902 and 1903. Cloth.

23d Annual Report, 1901-2, by Chas. D. Walcott. Cloth.
Pamphlets. Bulletins No. 205, 206, 207, 209, 210, 213.
" "Production of Sulphur and Pyrite in 1902," Struthers.
" "Production of Magnesite in 1902." Struthers.
" " " Asphaltum and Bituminous Rock, 1902." Struthers.
" "Production of Salt in 1902." Struthers.
" "Chemical Analyses of Igereous Rocks, 1884-1900."
" Report of the Ketchikan Mining District, Alaska, 1902, by Alfred H. Brooks.
" A Reconnoissance of the N. W. Portion of Seward Peninsula, Alaska, 1902, by Collier.
" Geology and Petrography of Crater Lake National Park.
" Water Supply and Irrigation Papers, Nos. 65 to 79 incl. 1902-3.
" The Production of Mineral Paints in 1902.
U. S. Census Office Bulletin, "Street and Electric Railways." Pamphlet.
House of Representatives, Preliminary Examinations, Surveys, Projects and Appropriations.

BOOK NOTES.

The Alternating Current Transformer. By F. G. Baum. Cloth, 6 x 8 inches, 195 pages, 122 illustrations. New York. McGraw Publishing Co. Price, $1.50.

This book originated in a course of lectures delivered at Leland Stanford University, and is intended as a practical description of the transformer, together with a scientific treatment of the principles underlying its actions.

After a chapter on elementary principles, a transformer diagram, with graphical representation of pressure and current relations is given. In a note preceding Chapter II the author recognizes the confusion produced by that diagram where the separate effects of primary and secondary current are considered. In the following chapters is presented the more proper study of the transformer, by showing the secondary E. M. F. as due to the changing magnetic flux, but the author has unfortunately adhered to the now somewhat old-fashioned diagrams with counter clock-wise rotation. It would have been better in a modern book, had the very clear and logical polar coördinate diagrams and explanations as first shown by Steinmetz been used. One good feature of the book is the auxiliary diagram of resistances and reactances accompanying many of the vector diagrams to show the physical meaning of the vectors.

The chapter on Regulation is good, as is also the following one on Efficiency, which has practical information of value. In Article 50 of that chapter the author, referring to methods of cooling transformers, states, "The square inches of exposed surface should be more than *twice* the number of watts to be radiated; see Fig. 46." A rise in temperature of 50 deg. C. is considered the limit for operation. Fig. 46 shows a radiation of almost 4 square inches per watt for oil cooled transformers, and more than 6 square inches per watt for air cooled. The *twice* in the sentence quoted is evidently too small.

Commercial testing of transformers is well described, but more as if written for the general reader only, than for the student also. No mention is made of various meter connections to eliminate the error introduced by the energy absorbed by the meters. While this is sometimes of small importance in central station testing, it is highly desirable that the student should appreciate the extent of the error thus introduced. The first paragraph of Article 61 leads one to believe that the iron loss varies directly as the frequency, which is true only of the hysteretic loss. In testing transformer iron the author has found the hysteresis loss to be proportional to a little less than the 1.5 power of the magnetic density. The exponent of B given by other investigators lies between 1.55 and 1.6, this latter figure being the one used by Steinmetz.

In Article 64, referring to the use of three-phase transformers in Europe where three single phase transformers are used in American practice, it would have been more correct to have added—"In stations and substations connected to underground lines where the danger from lightning is nil, the single three phase transformer is now being generally used in America."

The chapter on Circuit Regulators, Constant Current Transformers, Series Transformers, and Voltmeter Compensators, contains much useful information.

Transformer connections is the subject of another chapter in which are shown the various connections generally used in practice. Then follows a chapter illustrating some of the principal commercial types of transformers of both American and European manufacture. An appendix, giving an extract from the Rules and Regulations of the National Board of Fire Underwriters, relating to use of transformers, closes the book.

The entire treatment of the scientific part of the work seems rather superficial, and that is the principal criticism on the book. The use of R_1 for primary resistance, r_2 for secondary, and R_2 for resistance of load would be more logical if r_2 and R_2 were interchanged. On page 137 appears the statement "*In order to balance* the loads, one side of the transformer is usually connected 'delta' wherever possible." This statement should have been qualified, for, as it reads, it conveys the impression that a delta connection will correct any unbalance.

The discussion of the vector diagrams is not as full as it might be. The reader is told that such and such are the conditions, but the book does not always tell him why they are so, and this the student should know to properly grasp the theory.

Altogether the book is an excellent work for the general reader who is looking for practical information regarding the operation of the alternating current transformer, but as a scientific treatise for the engineering student, it leaves much to be desired. R. F. S.

Earthwork and its Cost. By Halbert Powers Gillett. 260 pp. with 50 figures and illustrations. Cloth bound, 5x7½ inches, price $2.00. Engineering News Pub. Co., New York, 1903.

This is a timely and valuable addition to literature which engineers and contractors should read. The introduction contains valuable advices, not only to the author's beneficiaries, but something every engineer in charge of construction work should study. So many young engineers imagine that because they have been clothed with supreme power, they are in charge of the details and must necessarily boss the contractors' men. Some will enforce the letter of the specifications, no matter when or where the work is done, and generally destroy good practical results. The author's varied experience entitles his book to a very favorable consideration on matters of engineering business.

We commend his painstaking diligence in gathering together a mass of useful information. It is tabulated conveniently for reference. Its wide use, as a reference book, making due allowances for surrounding variable and local conditions, is predicted. E. R. S

Statics, by Algebraic and Graphic Methods—Lewis J. Johnson, C. E., Harvard University. 8vo, 133 pp., 42 figures and 6 double page plates. John Wiley & Sons, New York. Cloth, $2.00.

This new book on Statics is a departure from the usual method of presenting the subject, in that the algebraic and graphic methods are presented in paralled and with equal thoroughness. This will be of great benefit to the student in enabling him to make his study a comparative one of the method of development and solution.

The particular merit of the work is its adaptability to the student's requirement in the obtaining of a knowledge of the subject that will enable him to apply it properly in his professional work.

The deductions are lucid, the successive steps being taken in logical order. Principles are not only set forth in this manner, but how statics is used in engineering practice is well illustrated in graded problems.

The system in which the subject is presented causes the student the more readily to comprehend it, because of the close relation maintained between the two methods. The fact that one solution serves as a check upon the other makes this presentation valuable in practice as well as to the student of its pages. H. H. J.

The Slide Valve and its Functions. By Julius Begtrup, M. E. 8vo, 143 pages, 6 x 9 inches, 87 cuts and diagrams. D. Van Nostrand Co., New York. Price, $2.

The subject is presented in six chapters—Chapter I, The Common Slide Valve, which describes the various critical points of admission, cut off, release and compression. the primitive valve diagram, and Sweet's diagram, the effect of variable valve-travel multiporting, the motion of locomotive valves and how to set the engine on the dead center.

Chapter II, Improved Slide Valves, which describes the double-ported Marine, Allen, Straight-Line, McEwen, Ball partially balanced valve, Richardson Balanced, Thomas Balance, piston valves, as exhibited in the Ide, Westinghouse, Vauclain, and all free valve gear.

Chapter III, Four-Valve Systems, describing and discussing Corliss, Porter-Allen, Gridiron, Hill and Wheelock valves with dimensions and directions for setting Corliss valves.

Chapter IV deals with independent cutoff as exhibited in the Meyer, Rider, rotating eccentric, gridiron, Begtrup, Buckeye, McIntosh & Seymour, and Russell.

Chapter V describes the slide valve in pumps as exhibited by Blake, Dean Bros., Knowles, Davidson, Cameron, Worthington.

Chapter VI discusses the angularity of connecting and eccentric rods, the effect on the critical operations of the valves, and the corrective methods employed.

The book is neatly arranged; the diagrams and cuts were largely made for the author and are simple and clear. The book is very interesting descriptively, and the attempt to make the subject appear very easy by giving small prominence to valve diagrams may prove successful. The practical observations of what has been found desirable from experience are timely, and it is pleasant to the reader to be told outright that certain factors are unknown as yet, factors which many writers appear to assume the reader to know, because perchance they are not quite sure but that by a definite statement they may be exposing ignorance of that well known to others. With the large amount of literature using the Zeuner diagram, and the smaller but more recent using the Bilgrim, it would seem that any work on the slide valve ignoring these was incomplete, however well the diagram chosen might fit the needs of the author. P. M. C.

A Manual of Land Surveying. By F. Hodgman, Climax, Mich., Practical Surveyor and Civil Engineer. "The Land Surveyors' Best Pocket Companion." $4\frac{1}{4}$ x $6\frac{1}{2}$ inches, flexible morocco and flap, 514 pages. Prices, $2.50.

"Surveyor's Tables," being the tables taken from the "Manual of Land Surveying;" flexible morocco, bound up with 32-pages cross-section paper for memoranda. Star edition. Price, $1.50. Published by the author at Climax, Mich.

The first of the above books is especially adapted to country surveyors who are not so fully occupied by their professional work, but that they will find of much service the easy and plain formulæ for the solution of such problems as may come before them. The many tables are clear, well arranged, and should be of great benefit in their field work. The surveyor's instruments and their adjustment, etc., are well described, which renders the book of value to students.

Of great value is the record of sundry decisions of the courts pertaining to subdivision of land, the relocation of disputed lines, and the establishment of corners, the limits of property along a stream or body of water, etc., etc. Undoubtedly this is the best treatise on these matters, in print. To many country surveyors whose practice is confined to survey work, these books would supply all their needs. F. C. R.

Municpal Public Works, Their Inception, Construction and Management. By S. Whinery, Civil Engineer. 8vo., cloth, 248 pp., price $1.50. Macmillan & Company, New York, 1903.

This is a timely publication that should be hailed with satisfaction by municipal officials everywhere. The author shows a thorough familiarity with the various phases of municipal administration of which he treats. While he brings out nothing particularly new, he sets forth in clear and comprehensive language the errors and abuses existing to a smaller or greater extent in all communities, and has a suggestion for improvements in each case. The book can be read with profit by the official who is a professional man as well as by the one who is a layman. The latter, particularly, will in a short time learn, through the reading of this book, many lessons that he would learn by experience only after considerable time of service. By following the advice given in the book, municipal officials would confer great benefits on the communities they serve, as well as on themselves The public works official should not fail to avail himself of the opportunity of reading this book. J. E.

A Manual of Practical Hygiene. By Charles Harrington, M. D., Assistant Professor of Hygiene in the Medical School of Harvard University. Second edition, revised and enlarged. Philadelphia; Lea Brothers & Co. Cloth, 6 x 9 inches; pp. 760; 12 plates and 113 figures in the text. $4.25 net.

In a science that has been making such rapid strides in later years, it is not to be wondered at that a book, to be complete and abreast of its time, must be rewritten in "a little more than one year." This shows also vitality and true merit in a book. Altogether it is comparatively complete and in portions it is quite an exhaustive study of the subject. The chapter on foods is very interesting and instructive. The novice is familiarized with the compositions and definitions of foods and then carried through a thorough discussion of each variety. A more extensive presentation of the subject of meat inspection would have added to this chapter and made it of more assistance to slaughter house inspectors. The chapter on Milk is one of the best features of the book. That alone should recommend the book to physicians.

In the chapter on Air the subject of ventilation is skillfully handled. It, as well as the chapter on habitations, schools, etc., would be profitable reading for builders and architects.

"The disposal of sewerage," and "the disposal of garbage," are questions that many large cities are attempting to solve to-day. Nearly all the methods in use, including Maul's Warings, Cameron's septic tank, and the Scott-Montcrief systems, are explained with the advantage of each according to location.

The Spanish war taught us all a lesson in military hygiene, and it is good to see the lesson brought out by the author. Now that some of our medical schools have established chairs for the study of tropical diseases we may expect a lowering of the frightful mortality that attended the advent of our soldiers in Cuba, Porto Rico, and the Philippines.

In the limited space allotted to this subject one feels that the author has not allowed room to do himself justice. "The relation of Insects to Disease" is a modern study and as yet in its infancy, with unlimited room for research and study.

The balance of the book, except the chapter on Vaccination and preventive innoculation, treats of subjects, in the study of which there has been little or no advancement.

The author has certainly availed himself of results of modern research and study in the compilation of this work. He has presented it in an attractive manner so that it would be interesting even to the novice.

It recommends itself, not alone as a text book, but as a reference book for the engineer, architect and scientist, as well as to physicians. Dr. W. M. T.

The Rise and Progress of the Standard Oil Co. By G. H. Montague. Harper & Brothers, New York, Publishers. Cloth, 5x7½ inches, 143 pages, price, $1.00 net.

The public is uneasy as to the eventual results of the so-called "Trusts." It questions whether, in the long run, great combinations of capital and of labor will tell for national prosperity, and whether individuals will not be oppressed by increased prices. Hence it reads with interest whatever studies are published on the subject.

The first and most successful of these combinations was that of the Standard Oil Co., and a number of books have been published about it. The present little work is a reprint of two articles published in the *Quarterly Journal of Economics* in 1902 and 1903. It was undertaken by the author while Ricardo Scholar in Economics at Harvard University for the year 1900-1901. He has gathered with laborious care the facts brought out by the various official commissions and committees which have investigated the management and out-growth of the Standard Oil Co. These are co-ordinated so as to form a connected history, and the author expresses but few opinions of his own. These opinions are mainly favorable to the men who with such extraordinary brain power have developed this giant trust by taking advantage of business opportunities. O. C.

Flexure of Beams, Experiments Resulting in the Discovery of New-found Laws of Failure by Buckling. By Albert E. Guy. pp. 122, including table of contents. Illustrated with diagrams. D. Van Nostrand Co., N. Y., 1903. Cloth, $1.25 net.

The *American Machinist* said, upon introducing the contents of this book in its columns, that "The analysis and presentation of this subject in treatises and text-books are almost stereotyped. * * * This series of articles on the Flexure of Beams, for the first time in many years, breaks new ground."

This is an interesting little book. Setting out to design a simple cantilever beam of a given length and load to have the least volume, that is, to find the most economical form of a cantilever beam, the author found that the existing formulæ based on data of breaking strength give no help because they are indeterminate. He found, further, that the formulæ for deflection, when combined with those of strength, give only the ratio of the height to the length. He then tried a series of experiments on small wooden beams held in various positions, from horizontal to vertical, and his results show that the laws of buckling of beams are analogous to those of columns, as expressed by Euler's formulæ. For a column fixed at the base and loaded at the free end, his results check almost exactly with Euler's theory.

In this age of refinement of experimental apparatus in technical schools and testing laboratories, we are too apt think that we must have a complete laboratory full of appliances to discover or prove up some law of every day application. This book shows a good example to the contrary. Means of weighing up to fifty pounds or so, of measuring thicknesses up two inches and lengths up to twenty-six inches, and a few pieces of apparatus to be had of any ordinary machine shop, some carefully selected wood and two or three carpenters tools were about the author's equipment.

Future experimenters, with more refined apparatus, greater variety and elaboration, will no doubt modify the value of his constants and may qualify his statement of principles, but his apparatus was so simple that we are liable to overlook its ingenuity, and his results are so important that the *American Machinist* appears justified in the statement that "Mr. Guy's articles are a distinct and notable addition to the science of engineering, and we consider that to be the means of their publication is a rare privilege." J. C. B.

Railroad Curves and Earthwork. 194 pages and 4 double page diagrams.

Field and Office Tables. 293 pages. By C. Frank Allen, M. A. S. C. E. Spon & Chamberlain, New York, 1903. 2 vols. flexible leather, 4x6 inches, $2 00 each.

These two books, taken together, will be highly appreciated by the practical railroad engineer, and by the college professor interested in railroad location and construction, and in the study of the same. They are undoubtedly a decided advance over the field books now in comon use. Many new formulæ, problems, and tables are presented, and the chapter on railroad easement is given in conjunction with the other matter on railroad curves, which in itself is desirable, as it reduces the number of field books to be carried by the engineer.

It is probably true that there are, and henceforth always will be, in this country at any rate, many more railroad engineers that are engaged in maintenance work than in new location and construction. For such, these books do not cover the ground as fully as would be desired. For example, in the problems on turnouts, still more stress could be made, or problems more typical could have been given, and some of the problems as given could well be changed to emphasize more fully than has been done that the center line of a turnout is *not* a regular curve, but that it is a straight line through the switch length, a regular curve for a certain distance possibly more easily calculated than by the method here given, and then a straight line through the whole length of the frog, and that the engineer's duty, in staking out a center line for a proposed turnout to connect with an existing track center line (or with another proposed line for that matter), is better done by first locating the frog point and then starting for the line outside the turnout at a point some feet ahead of that on the frog tangent, and with the direction of the frog tangent.

The majority of practical engineers who use, or wish to use, easement curves would no doubt have preferred to see, in such a work, a simple demonstration, or the simple facts from such demonstration, of the essential points of the so-called "Holbrook" spiral, or a curve, the curvature of which increases exactly as the distance from the tangent end, giving just the simple relations that exist between the spiral offset, (K L in demonstrations given), the length of the spiral and the degree of circular curve at the end. In spiraling on maintenance work the engineer has more often to deal with curves of odd degree than with integral degree, and the tables here given would help but little.

It is probable that most engineers would rather take out contract quantities of earth work from tables arranged to obtain readily from notes, first, the cross-section areas at each place noted, and second, the volume in cu. yds. per 100 ft. for average end areas. This would be much less confusing to most of us than to use the tables given.

In general, a book covering more than the field of these two books can be written, which will not be so large as these two, and which would have much information and some tables that these have not, but which would certainly answer better the uses and needs of the practical railroad engineer, either in the field or office.

W. M. T.

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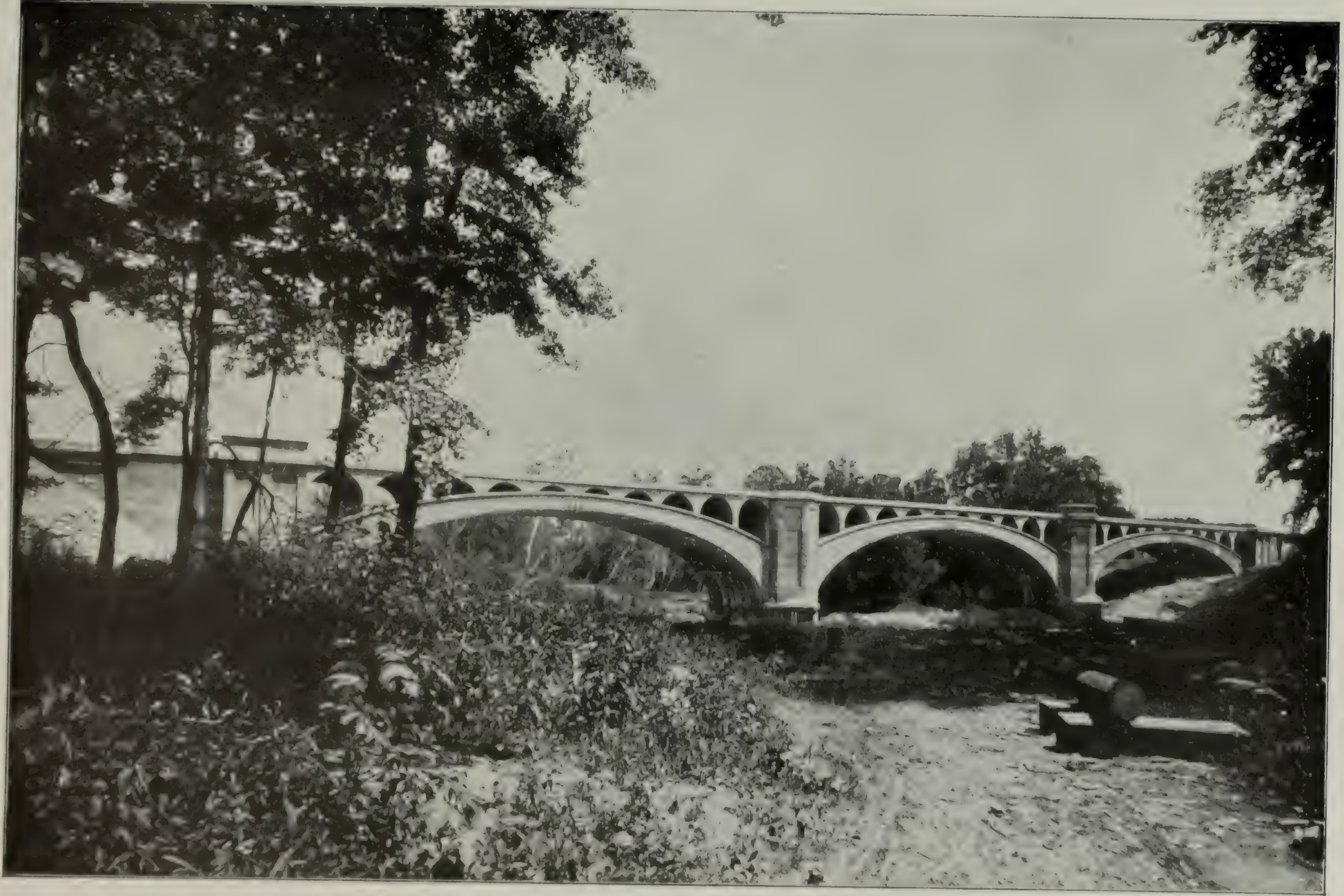

SOLID CONCRETE ARCH BRIDGE, NEAR CARBONDALE, ILL., I. C. R. R.

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THE DEVELOPMENT OF A NEW COAL FIELD IN COLORADO.

L. B. Merriam, M. W. S. E.

Presented Sept. 2, 1903.

Colorado! The land of precious metals and the cowboy, is fast becoming the land of structural metals and summer resorts. The value of fuel and iron products is making rapid strides towards becoming the greatest of the diversified products of the State. The largest corporation producing iron, steel and fuel of all classes is the Colorado Fuel & Iron Company. A map showing the 54 properties of this company in Colorado, Wyoming, Utah, and New Mexico, is shown in Fig. 1. The largest single plant of the company is the steel works at Pueblo, designed to be the largest individual steel plant in the United States, embracing furnaces, Bessemer convert-

Blast Furnace at Minnequa, Colo.

ers, and open hearth plants; the products of all to be manufactured into iron and steel castings, rails, and structural and industrial steel of all classes, including wire and tin plate. This plant is not yet complete, but has grown in the last few years from a small plant producing only rails and merchant bars in small quantities, so that within a year the statement above will be true.

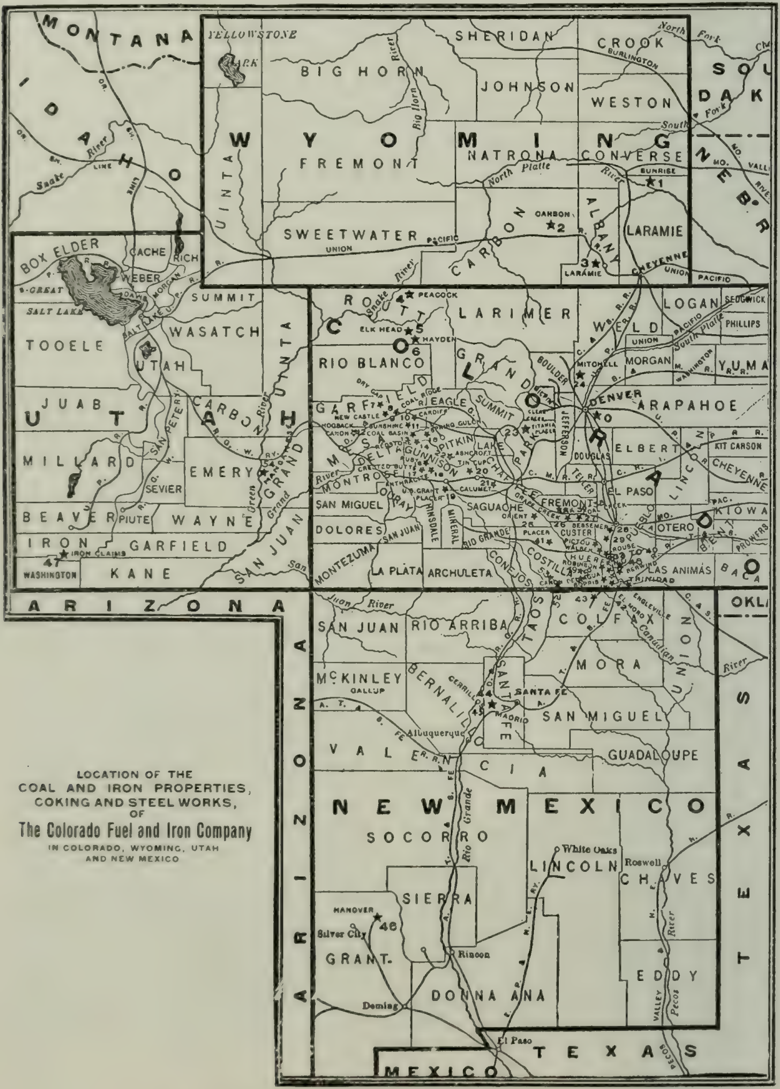


Fig. 1.
Map Showing Mines of Colorado Fuel & Iron Co.

There are now five modern furnaces and the open hearth plant in operation. This growth, in connection with the increase in the production of the rarer metals and the general industrial development of the Rocky Mountain region, has caused an immense increase in the fuel requirements of this region. To meet this increase the Colorado Fuel & Iron Company has increased its plant from 1,065 ovens of a few years ago, to 3,016 ovens, and has increased its coal production in a still greater ratio.

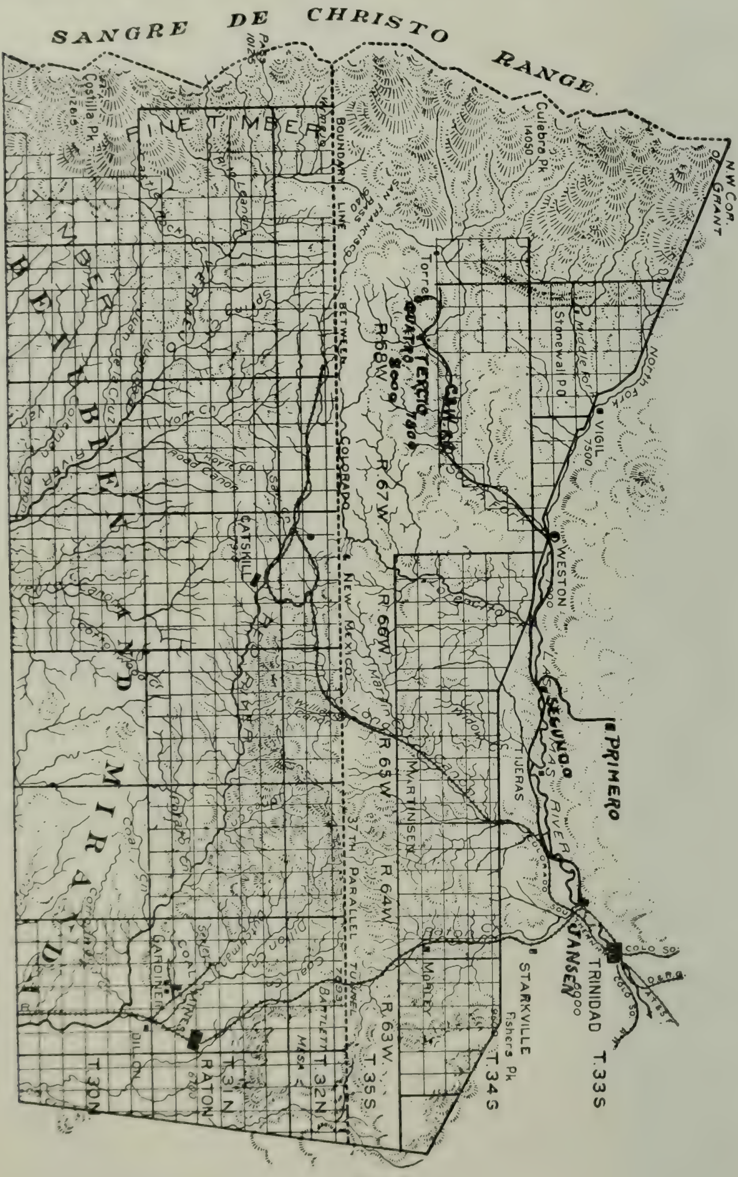
A large portion of this increase in fuel production has been through the development of properties in the southern part of Colorado, along the eastern slope of the mountains, and the coke increase is largely in the Purgatoire Valley. Some of the oldest coke ovens in the State are located at Sopris, Starkville and El Moro. These have produced a prime quality of coke, and when the Colorado Fuel & Iron Company obtained control of a large portion of the Maxwell land grant, it started at once the devolpment of this region by the construction of a railway known as the Colorado & Wyoming Railway, from Jansen on the Atchison, Topeka & Santa Fe Railway up the Purgatoire River. Surveys were started late in the year 1900 and the line built to Primero by midsummer 1901. Coal development work was started about Christmas, 1900, at Primero, and in less than fifteen months the mine was producing 2,500 tons of coal daily. Then 800 coke ovens and two coal washers were built at Segundo. The railway was meanwhile pushed to Tercio and finally to Cuatro.

At Tercio, 600 coke ovens have been built, with provisions in the lay out plan for from 600 to 1,200 more, as the need develops. One coal washer has been built and another is under construction. Coal mines are being developed at Tercio and Cuatro, and a reservoir site located in a large natural basin between Cuatro and Tercio, where one earth dam of 67 feet maximum depth, and 1,000 feet long, together with a smaller dam about the same length and 18 feet high, will impound about 750,000,000 gallons of water.

The coking coal of this district analyzes as an average:

	Per cent.
Fixed carbon	60
Volatile matter	30
Ash	10
Total	100

To get the best results, slack and the smaller sizes of coal are required for coking. This gives the opportunity of using the entire output of the mine to good advantage. All coke in this district is produced from washed coal, the method being to elevate the coal to the top of the washery, where it passes through a toothed roll crusher, thence it passes over either shaking or revolving screens, which sort it to the proper sizes. From there it passes to the jigs, arranged to wash that particular size; thence it passes through a rotary screen and is partly dried. The sludge, passing to pumps, is trans-



Fig, 2.
Map Showing Colorado and Wyoming Railroad.

ferred to sludge bins and settled; the coal going to a disintegrator, where it is broken very fine, and from whence it is elevated to bins called larry bins. The coal and settled sludge is loaded into cars called larry cars, which carry enough to charge one oven; these cars are run out over the ovens on a track, consisting of 12-inch I-beams resting directly on piers built up in the triangular space between the ovens. These beams are held to gauge by pipe and bolt separators, and the rail is clamped to the top flange of the I-beams.

The cars have a bottom discharge with a small chute on each side, so as to unload directly into the smoke hole of the ovens.

Coal in this vicinity is mined almost entirely by slope or entry method, there being no shaft mines in the district so far as I know. At Primero the coal lies flat or nearly so, the seams run from four to six feet in thickness. There are several main entrances on each side of the gulch; the tipple is continuous across the valley, and is a full double tipple with two comple outfits of Mitchel tipples, screens, etc. Cars brought down from either side may, however, be taken across and unloaded at the place where cars from the other side are usually dumped, thus providing for accidents or an extra heavy production from either side of the valley.

Coke Ovens at Segundo.

Haulage on the inside is by mules and electric motors; on the outside by Porter steam locomotives of 3-feet gauge. Mine cars being large and of this gauge, Primero slack and nut coal is loaded into Ingoldsby standard gauge dump cars at the tipple, and hauled to Segundo in train lots; there it is dumped into a track bin which carries a double track and has a capacity of 800 tons of coal. This track bin has a link-belt conveyor, which carries the coal to the elevators of the washeries. The storage capacity of the washed coal or larry bins at Segundo is about 1,300 tons, or enough to charge nearly one-half of the 800 ovens; and inasmuch as all coke is

48 or 72-hour coke, half, or less than half, of the ovens are charged daily. This gives a 24-hour supply.

At Tercio and Cuatro the coal lies on a pitch of from 40 degrees to 60 degrees, and the method of mining at Tercio is by entries nearly on the strike line of the coal, which are driven on a uniform rising grade of 0.5 per cent. Entries being 350 feet apart on the seam, rooms are driven up the pitch 300 feet, and the coal loaded from the chutes at the neck of the rooms. Gravity inclines are used to bring the coal down from the upper entries in some cases, and in others a room from the lower entry is to be driven up through the mouth of the upper entry, and the coal from the upper entry dumped into the room and reloaded below.

One entry is located about two miles from the tipple, and Porter steam locomotive haulage is used. The mines near the tipple use mule haulage, outside and in. The tipple is like the one at Primero in regard to extending across the valley, but in addition it is so arranged that any or all of its coal can be dumped direct into the track bin which passes under the tipple.

A novel feature of the track bin consists of a kick-up track, with a gravity switch-back, which returns the empty cars to a side-track below and beside the track bin after they have been dumped.

The Cuatro mine is being developed by a slope diagonally down the pitch, on a grade of about 30 per cent. After being hauled to the mouth of the slope by a hoisting engine, the mine cars are taken to the tipple 6,000 feet away by an endless rope system of haulage. The grade of the 6,000 feet of tramway is down toward the tipple, and is about 5 per cent as an average, having a range between 3 per cent and 8 per cent. This is a double track system and is straight in alignment.

The Colorado & Wyoming Railway is a thoroughly well constructed road, banks being built 16 feet wide on top, and the roadway in excavation being 18 feet in rock and 20 feet in earth. It is laid with 75-pound and 80-pound steel rails. The ties are pine, mostly native, but some are Texas pine, the latter being much the best, but the native ties are available along the line, and the Texas ties must be shipped in. All curves have tie-plates on every tie, thus making the native tie quite satisfactory. All curves above four degees are spiraled, using Searles' spiral. All maximum grades are compensated.

The characteristics of the line are as follows:

MAIN LINE.

Sharpest curve....................	6 degrees.
Number of curves...	83
Length of curved line..............	13.22 miles.
Length of straight line............	17.83 "

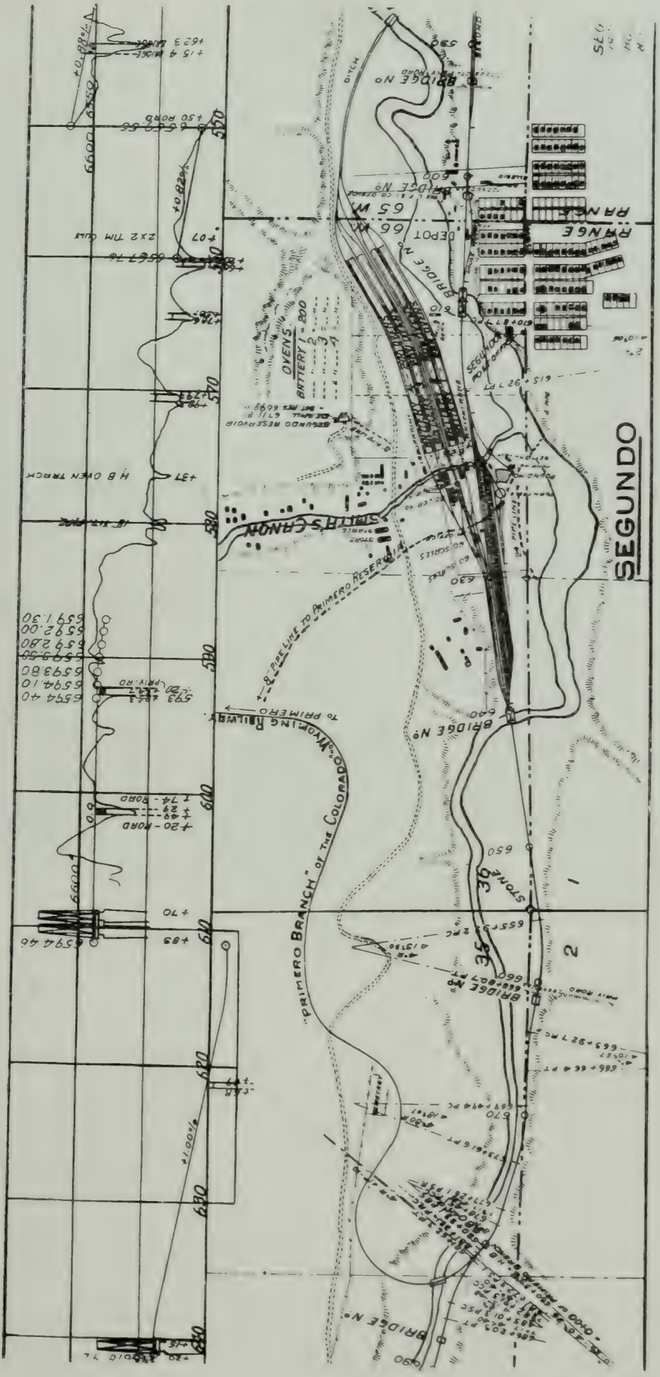


Fig. 3.
Map and Profile of C. & W. Ry. at Segundo.

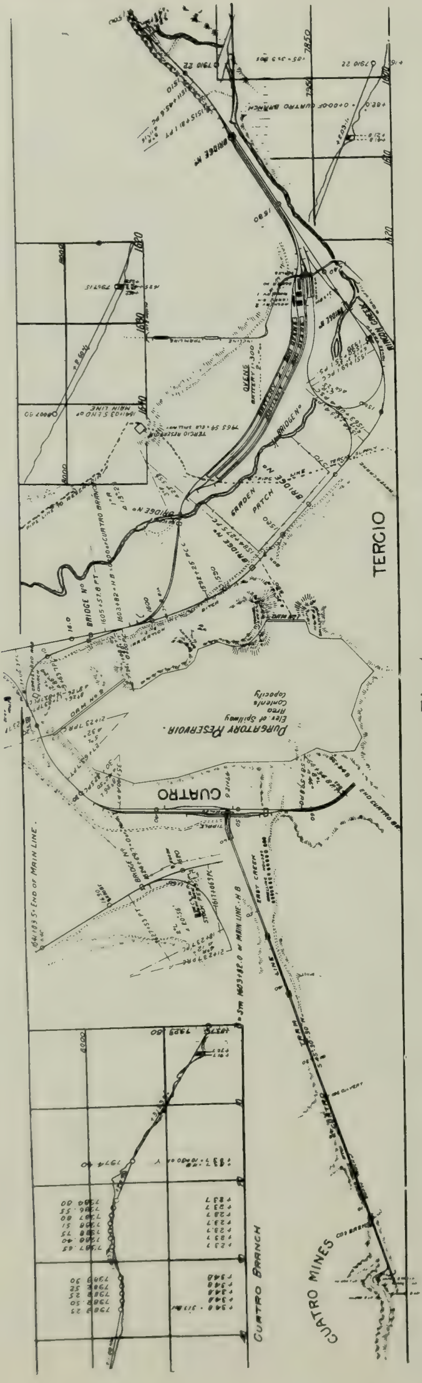


Fig. 4.
Map and Profile of C. & W. Ry. at Tercio and Cuatro.

GRADES.

Jansen to Primero, maximum grade	1 per cent.
Primero Jc. to Weston	1¼ per cent.
Weston to Tercio	2 per cent.
Total rise	1,831 feet.

PRIMERO BRANCH.

Sharpest curve	12 degrees.
Number of curves	12
Length of curved line	2.33 miles.
Length of straight line	0.72 "

GRADES.

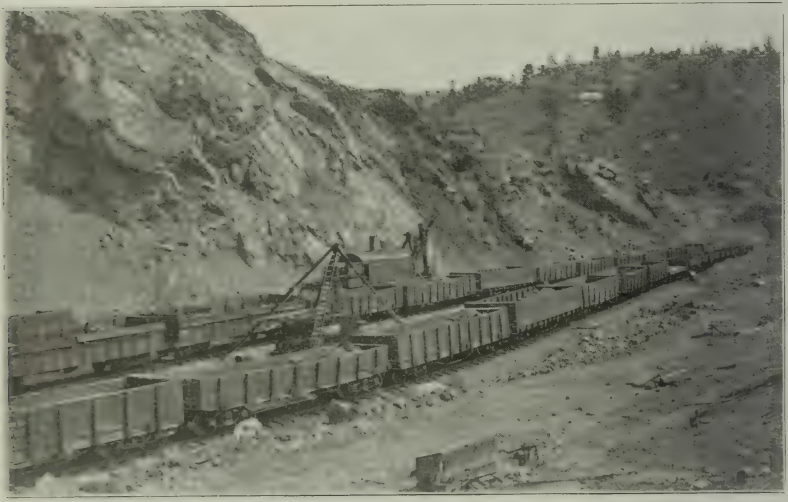
Maximum rate	2 per cent.
Total rise	300 feet.

View of Segundo - - Coal Washery.

The yards are ballasted with coke breeze, and there are nine miles of stone ballast between Jansen to Segundo, the rest of the line having dirt ballast. There are six steel bridges on concrete abutments, two of two spans, and four of one span each. All spans are 120 feet, and of the same standard form of truss. The present traffic is slightly in excess of 100 carloads per day. I show views of the tracks, ovens, etc., at Segundo and Tercio. The plan of coke ovens as built at Tercio are with 10-feet wharf walls. The wharf walls are generally made lower, 4 feet above rail, and built of stone, but at Tercio only high coke-rack cars are to be loaded, and higher wharf walls are used.

With the development of the resources of the Purgatoire Valley the sociological development has not been neglected. Towns have been established at Primero, Segundo and Tercio, and when I say towns I do not mean camps as they are generally seen. Streets are laid out and houses of good design and fair construction are built in lots as ample as the topography will permit. These are painted in good taste, and houses of different design so grouped as to give all the appearance of a thrifty town.

The Purgatoire river flows through Tercio and supplies by gravity through a 26-inch wooden stave pipe a reservoir of 750,000 gallons capacity, which is located about 100 feet above the grade of the washery, and supplies the town and plant with pure mountain water. Trinidad is 214 miles from Denver and almost due south.



Iron Mine at Sunrise, Wyoming.

The other points mentioned above, along the C. & W. Ry., are as follows:

Jansen, at the junction of the Atchison, Topeka & Santa Fe R. R., is 2.1 miles from Trinidad; Sopris is 4.6 miles; Segundo is 14 miles; Primero is 17.6 miles; Tercio is 31.4 miles, and Cuatro is 33.2 miles.

The store buildings of the Colorado Supply Company are models of old mission and Swiss architecture. Ample school houses are built, in which the county maintains first-class schools. Kindergarten, sewing and cooking schools are maintained by the sociological department of the Colorado Fuel & Iron Company. Each town is laid out into street and alleys, and is provided with pure drinking water and fire protection, with better laid out and constructed water systems than is to be found in most Eastern towns of equal population.

DISCUSSION.

Mr. Warder—Mr. Rowe, M. W. S. E., told me very lately of an interesting fact in connection with the examination of a certain coal property, the "Cerrillos," for the A., T. & S. F. Ry. about twenty years ago. He found three different workable beds, 3 to 3½ feet thick, of bituminous coal, in walking up a cañon, where the outcrop showed and the deposit was being worked. Above these there was another bed of coal, which was a hard anthracite and not to be distinguished from Pennsylvania anthracite. The occurrence of this bed of coal above the beds of bituminous coal is in direct opposition to all of our earlier teachings, in regard to the relationship between the geological history of bituminous and anthracite coal deposits. A study of the anthracite coal fields of Pennsylvania indicate that they have been metamorphosed from bituminous deposits under the effect of heat and great pressure. Mr. Rowe said there were four different beds occurring at various distances apart, but all comprised within 1,000 feet range of the elevation, and that the outcrops showed along up the cañon within a distance of a few miles, and with this uppermost bed of anthracite. A further investigation showed that the top bed was capped by a 100-foot bed of sandstone, and above that a lava cap of considerable thickness. In this case it was evident that the heat of the lava flow and the weight of the sand rock had converted the soft coal into an anthracite. Here exist the conditions that many would have said to be impossible—a bed of hard anthracite coal overlying sundry beds of bituminous coal.

A further interesting discovery was made by Mr. Rowe, in connection with these deposits—that is, that the sandstone at the bottom of the cañon and below these coal beds carried a good deal of natural or mineral oil, which probably had been yielded by the carbonaceous deposits above.

Mr. Powell—These beds of coal in Colorado are about as far south as any workable coal is found, are they not?

Mr. Warder—Mr. Merriam speaks of some of their properties being in New Mexico.

Mr. Powell—That belt which extends about as far south as Albuquerque?

Mr. Warder—Yes.

Mr. Powell—I had to go south one time and was told then by Mr. Robinson that in Mexico there was no workable coal.

Mr. Finley—Is it that it isn't there, or that they have not found it?

Mr. Powell—They have made a very thorough search, particularly the Mexican Central Railway Co., and did not find any. There is some very poor coal—lignite—at a few places. All the coal used in Mexico is imported, excepting that which comes down through Colorado.

Mr. Karner—In Mexico they have made a very extensive but unsuccessful search for coal.

Mr. Powell—At the present time the most of their coal comes in through Tampico.

Mr. Warder—From Europe?

Mr. Powell—Very largely.

Mr. Warder—Alabama coal, too, I suppose.

Mr. Powell—Yes. A great deal of coke comes from Germany, and is that produced under the bi-product process. It averages about the size of small egg coal and looks more like the gas house coke.

Mr. Finley—Does any one know how that Colorado coke compares with the Connellsville coke?

Mr. Powell—It will not carry as heavy a burden in the furnace as the Connellsville. It has not the ringing sound that the Connellsville coke has, and hasn't that bright silvery color.

Mr. Finley—They are using it practically for the same purpose. If it is not as good, I should think they would be at some disadvantage in comparing it with the Pennsylvania coal.

J. V. Schaefer, M. W. S. E. (by letter)—It may be of interest to members of the Society to know something more in detail about the matter of washing the coal referred to in Mr. Merriam's paper. I believe the analyses given by Mr. Merriam must be analyses of the washed coal, as the unwashed slack coal of Colorado runs very much higher in ash. This ash is largely due to the large amount of bony coal contained in this coal. The general practice of the Colorado Fuel & Iron Co. thus far has been to divide this coal in washing, into only two products, namely, coal and dirt. In so doing the bony coal has been largely retained in the washed coal, which for this reason has run high in ash. They decided upon this, because, owing to the large amount of bony coal they could not reject it in the refuse, as the loss of product would be too great. They are now, however, contemplating making such changes in their washing plants as will enable them to make three products, viz.: Washed coal, dirt and middlings. These middlings will consist of the bony coal which is intermediate in specific gravity between the clean coal and the dirt and they will avoid the loss due to this shrinkage of product, by taking the middlings out of the coal, and using these middlings for fuel. At the present time they are using mine run coal for fuel.

The jigs which the Colorado Fuel & Iron Co. adopted quite a number of years ago and which are used throughout all their plants are the Forrester jigs. If they decide to change their design, so as to make middlings, they may decide to retain the Forrester jigs for the coarser sizes and use some form of Feldspar jig for the finer sizes.*

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*For a description of coal washing jigs see JOURNAL——; Vol. VI, pp. 511.

Mr. R. D. Seymour, M. W. S. E. (by letter).—The very interesting paper read at your last meeting, by Mr. Merriam, on the development work done by the Colorado Fuel & Iron Company, in the Raton Coal Field in Huerfano and Las Animas Counties, in this State, is a very timely one and it calls the attention of the W. S. E. to something that seems to be very slightly known in the Mississippi Valley or the eastern part of the United States, and he might have extended his paper and covered the work that has been done in the Crystal River region in Pitkin County, by the same company.

One could write a book on the undeveloped coal lands of our State, and then not cover the subject, and I will limit what I have to say to a plain statement of facts. Without counting the Raton Field, which Mr. Merriam writes about, there is lignite coal of very good steaming qualities, that extend from Pueblo to the northern border of the State, nearly 200 miles along the eastern slope of the mountains. We have in the Grand River Field on the western slope, deposits of coal of greater area and varying qualities, than is found in Pennsylvania and West Virginia. The greatest length of this field in Colorado is 150 miles and the breadth from the south end of Grand Mesa, due north to the opposite border, is 103 miles, while the distance across the field along the western line of the State is about 60 miles. In Colorado the field contains approximately 6,950 square miles. In this field can be found different qualities of coal, varying from an excellent grade of anthracite through several grades of bituminous, that furnishes an excellent quality of coke, to the different qualities of lignite, that compares very favorably, for domestic and steaming purposes, with the Indiana block coal, of which a large quantity is used in Chicago and neighboring cities.

The Colorado Fuel & Iron Company are working in several places along the Midland Railway in Pitkin and Garfield Counties, and the coke produced from the ovens at Redstone, Cardiff and Newcastle, compares very favorably with the coke that is produced in Pennsylvania, and it is all used by the various smelters and in the iron furnaces of the company at Pueblo.

These coal deposits will eventually make Colorado a very rich State, and it will not be many years before manufacturing will be the chief industry of this section, instead of mining for gold and silver. The only thing, now, that prevents the full development of our resources, is the policy of the railroads, whose managers think they can continue to keep the rates on all kinds of manufactured goods manipulated, so that anything manufactured in this section, is barred out of markets, which should be controlled from this end. Time will correct this discrimination, however, and the example set by the

Colorado Fuel & Iron Company, in using modern methods in the development of their property, will be followed by others, and manufactured products of the mountains will be found in the near future competing with the east in the markets of the Mississippi Valley.

It is very likely that some members of the Society will think that some of the statements made in this letter are too optimistic, and that it comes from some misguided member, who has allowed the high altitude and our glorious climate to warp his judgment, and for the benefit of any such, I attach the following extracts from reports made by others, who being experts in their line, and having made their reputations, cannot be accused of being too enthusiastic:

Mr. R. C. Hills, in an article on the "Coke Fields of Colorado," written for the Geological Survey of the United States and published in the "Mineral Resources of the United States," in 1892, gives a very interesting account of all the coal that had been prospected up to that date.

Mr. William Weston, a mining engineer for 20 years in Colorado, and well known all over the State, and Mr. Etunne Ritter, a doctor of science in the Geneva University, mining engineer of the Ecole des Mines, in Paris, and formerly on the geological surveys of France and Algeria, made an examination of the coal deposits in Northwestern Colorado, and they report that there is enough coal in the Yampa Fields, which comprise an area of 900 square miles, to supply the United States for 100 years. The superior quality and variety of the coal is surprising, and there is a practical route for a through line of railroad, through the center of the field.

Professor Arthur Lakes, the well known geologist, says the quantity of coal is practically unlimited. It would be safe to say, that there is 25 feet thickness of excellent coal, some of it anthracite, over the whole area, and that 50 feet would not be an exaggerated estimate. It is all of first-class quality, part of it bituminous and coking, and part of it anthracite of a quality that compares favorably with the best grades of Pennsylvania coals of the same kinds.

The Richmond *Times-Dispatch*, of August 2d, reports an interview with Mr. David H. Moffat, President of the First National Bank, of Denver, and President of the Denver, Northwestern & Pacific Railway, now under construction, in which Mr. Moffat says, "When the 'Moffat Short Line' is completed, anthracite coal of a quality equal to the Pennsylvania, will be delivered as far east as Chicago, for $5 per ton."

"The anthracite coal of Routt County will be less than 200 miles from Denver, and can be delivered in that city at competing prices; also monopolizing the market of Kansas and Nebraska, and successfully competing at Mississippi River points with the anthracite coal of Pennsylvania." "Professor Arthur Lakes, who for many years occupied the chair of geology at the Colorado State School of Mines, found the Routt County anthracite to be hard, firm, and compact, breaking into large shining blocks. Fragments that have lain for years on the surface, show no sign of slacking, proving it to be capable of being carried in stock for an indefinite time, without deterioration."

The high quality of the Routt County coal is proven by comparing the analysis of like varieties of anthracite and bituminous coals of Pennsylvania.

Mr. Geo. S. Rice, M. W. S. E. (by letter)—I note that Mr. Merriam speaks of the Colorado Fuel & Iron Co. having obtained control of a "large portion" of the Maxwell Land Grant. As I am somewhat familiar with the extent of the latter, and the importance of its coal deposits to New Mexico, I venture to suggest that the author's word might be misleading to those not acquainted with the "Las Animas" coal field (along the Las Animas River, sometimes called the Purgatoire River), and the Raton Mesa coal field; while these are coextensive, the bulk of the latter lies south of the Colorado-New Mexico State line; the purchase mentioned was of all the Colorado holdings of the Grant Company, embracing an area extending from Raton Pass on the A., T. & S. F. Ry., and running west along the State line for about 50 miles, the width north from the State line being about 6 miles at the east end and 18 at the west end. All that part of the grant lying south of the State line and in New Mexico, an area of nearly 50 miles square, is retained by the Maxwell Land Grant Co. The northern quarter of this in the Raton mountains or plateau is underlain with coal measures containing more or less workable coal. Coal has been extensively mined for 30 years in the vicinity of the town of Raton, and at the mining towns of Blossburg and Gardiner. This coal has supplied the A., T. & S. F. Ry. as far west as California, until the more recent use of California oils on the locomotives has displaced the coal nearly to the western border of New Mexico. The screenings are made into coke, which is used in the smelters of New Mexico, Arizona and old Mexico.

Unfortunately enormous areas of the coal seams under the Raton plateau, and along the Purgatoire, have been rendered worthless by lava. The Raton mountains are seamed with great dykes, which fill fractures resulting from the uplifting of the great mountain masses—the Sangre de Christo Range and the Spanish Peaks. These dykes, welled up from below, and spread over the once great plain, forming, as in the case of Fisher's Peak, a series of great terraces of lava 600 feet or more in thickness, capping the Laramie sandstone and shales which contain the coals. The Laramie is a division of the cretaceous, hence the coals are of a far more recent age than those of the carboniferous. In this connection it might be well to state, for the benefit of those who are not familiar with the Rocky Mountain region, that practically all the coals of that region belong to the cretaceous age—from lignites to anthracites. The carboniferous age is very poorly represented. I believe only one thin vein has been ascribed to it, a highly pitched vein two or three feet thick, showing near Golden, Colo., and which was once worked in a small way. On the other hand, the thickness of coals in the cretaceous is enormous in some parts of Colorado, Wyoming, and the Dakotas.

Only in the neighborhood of the eruptive masses have the coals been advanced from lignites through the successive stages of non-coking bituminous to coking bituminous, and in a few instances to anthracite, while the eruptives and the dynamic pressure incident to mountain uplifting have been beneficent in this respect, the process has not been one of slow ripening as with the coals of the carboniferous period, but the profound disturbances have destroyed, for mining purposes, many square miles of coal, to one improved and left intact. Hundreds of square miles of the Raton Mesa and Las Animas coals have been so destroyed—the seams having been cut to ribbons by the upwelling lavas, (mainly basalts)—these have not always been able to break through to the top, so have "intruded" into the several seams, burning it or else turning it into a "natural coke," which is stone-like and worthless, both from the density and admixture with lava. The Sopris mine mentioned by the author, which was where I had my first experience in mine development and coke oven construction some 15 years ago, was hemmed in on the west by such intrusive sheets. The early Blossburg mines in New Mexico had to be abandoned on this account, and the present Gardiner mines are on the point of abandonment from the same cause. At the same time the reserve of coal in these districts is very great and will last a great many years—possibly hundreds at the present rate of mining—but with constantly increasing difficulty to obtain, as the more available outcrop coal becomes exhausted. The Colorado Fuel & Iron Co., as indicated by the author, has been obliged to jump some 30 miles westward from its Engle, Starkville, and Sopris group of mines. Undoubtedly there are large areas of untroubled coal between, but not so good or available.

On the south flank of the Raton Mesa the Maxwell Land Grant Co. has started new mines in Willow Cañon, 15 miles west of their Gardiner mines, now about exhausted. A development further west has been made by the Rock Island Railroad Co. on the Dawson Ranch which lies surrounded by the grant. The Rock Island Company has built a 100 mile branch to reach this area, showing its pressing needs for fuel.

This Raton-Las Animas field contains practically all the coking coal of the vast range from New Mexico, north through Colorado and Wyoming. For this reason it is of great commercial importance, as it is relied on to supply the Denver and Pueblo smelters, and the great steel plant at Pueblo with coke. The supply of non-coking coal and lignite is vastly greater than of the coking coals, the amounts of the former in both Colorado and Wyoming being incalculable. The supply of coking coal in Colorado west of the main range is of vast extent, and the coal and coke therefrom much lower in ash than the "Trinidad" coke, by which commercial name the coal from the Las Animas mines is known. As to the Trinidad coke, it is somewhat higher in ash, even when the coal from which it has been made has been washed, than the Connellsville standard, but it is equally good in structure.

Owing to the heavy grades over the mountains, it is not likely that the coke made west of the range, in spite of its superior quality, can compete to any extent east of the range, as long as the Trinidad coke can be produced as cheaply as it now is.

The foregoing supplements to some extent, Mr. Merriam's paper, and answers some of the discussion that followed, but I note what Mr. Powell says of Trinidad coke—that "it will not carry as heavy a burden in the furnace as Connellsville; has not the ringing sound that the Connellsville coke has, and hasn't that bright, silvery color." I do not know what experience Mr. Powell may have had with the Trinidad coke, but the recently constructed stacks of the Colorado Fuel & Iron Co. at Pueblo are, I understand, as large as any in the country, with the possible exception of a few; the Trinidad coke is used in them, and I understand it carries the burden all right. From Mr. Powell's commenting on its not ringing so much, or having a silvery color, I think he must have observed some of the 48-hour coke, which is purposely softer and more like gas coke, but is better adapted to use in the silver smelters. That for use in the blast furnaces is coked 72 hours and is hard and silvery.

Mr. Powell asks about the other coals in New Mexico. There is no coal developed or known south or west of the Maxwell Land Grant, except a limited area of thin and broken coal at White Oaks, near the south border, and the Cerrillos area at the western border of New Mexico where a limited amount of anthracite is found, in addition to some coking coal. While I am not personally conversant with this neighborhood, I assure Mr. Warder that this and similar occurrences of small beds of anthracite in the "Rockies" have been known and commented on by geologists for many years. The Cerrillos anthracite deposit of New Mexico was visited and commented on by Professor Blake in 1857, by Professor Newberry in 1859, by Dr. Le Conte in 1869, by Dr. Hayden in 1869, and afterwards by many geologists. It was opened by the A., T. & S. F. Ry. some ten or twelve years ago, and a very large coal breaker of Pennsylvania pattern erected. That mine, and some of the neighboring bituminous mines are now operated by the Colorado Fuel & Iron Co. under lease. The anthracite vein is rather thin—about three feet thick—and the volume of the output has been disappointing.

The first anthracite mine in the west, and for years the only one outside of Pennsylvania, was the "Smith" mine, four miles from Crested Butte on the west side of the main range, but surrounded by other mountain ranges. This mine was opened about 1881 by a Mr. Bell, and was afterwards operated by the Whitebreast Fuel Co., who turned it over to the Colorado Fuel Co. on its formation in 1887. The latter company afterwards combined in 1892 with the Colorado Coal & Iron Co. The property was worked until last spring, when the limited area was finally worked out. It was interestingly located half way up a high ridge, 900 feet above the valley, and over 9,000 feet above sea level. A gravity incline 1,800 feet long and 900 feet vertical descent took the coal down to the breaker and railroad in the valley. The outcrop of this 3 to 5 ft. seam runs around the ridge. In 1887, aided by some prospecting, I had little trouble in following and surveying around the continuous outcrop. A great eruptive mountain mass immediately to the north was probably responsible for the change of this coal to anthracite. What is considered to be the same seam becomes at Crested Butte a coking coal which produces a fine grade of coke. There it has been extensively mined and coked for years by the C. F. & I. Co. A dozen miles west of Crested Butte, near Ruby Peak and 10,000 feet above sea level, another patch of anthracite has been opened up and a coal breaker erected. The vein is thin, only 3 to 4 feet thick, and is highly pitched against the flanks of a high ridge, its outcrop line running zig-zag up and down the sides of the ridge. The presence of a heavy overlying intrusive sheet of porphyry has turned the coal into anthracite; further down, deep under the valley, and away from the influence of heat once given off by this lava sheet, the coal is unchanged from its bituminous stage, as disclosed by some deep diamond drill holes. The development of the mine has been rather slow, and the mining is very expensive.

These three mines, and a semi-anthracite mine in Arkansas, are, I believe, the only true hard coal mines with breakers, outside of Pennsylvania, in all the United States. I think it is not considered probable by geological authorities that there is reason to expect the finding of extensive deposits of anthracite in Colorado,— at least it is a case of being unproven, though countless rumors are always abroad. The geologic conditions surrounding the formations are altogether different from those of Pennsylvania.

It appears to me that in his deservedly glowing tribute to Colorado, Mr. Seymour is a little severe on the railroads in retarding the progress. The roads of the state are obliged to have steep grades —3 or 4 per cent. maximum grades, contrasted with ¾ to 1 per cent. in the middle west—and sharp curves in addition. The country is sparsely settled, and until the population grows enormously, there is no advantage in locating general manufacturing there beyond supplying the needs of the pupulation. Mr. Seymour neglects, in his comparison of fuel supplies, the middle west. Iowa, for instance, has at present a larger coal output than Colorado, and although of poor grade it is sufficiently good for power purposes, and is used by the railroads running to Colorado, half way across the intervening state of Nebraska. Missouri's output is nearly as much as Colorado's, while Illinois easily has the largest coal area of any state in the union, has an output second only to Pennsylvania, and can meet any demands manufacturing can make on it, and on the whole can be more easily and cheaply mined, barring labor conditions, than the coal of any other state, though it is, to be sure, only a domestic or fuel coal. For this reason, while not decrying the wonderful resources of Colorado, I doubt their serious competition in general manufacturing in the Missississi Valley, even with the most favorable railroad rates.

As to the newspaper interview attributed to Mr. David Moffat, in which he is said to state "when this line is completed anthracite will be delivered as far east as Chicago for $5.00 per ton," it cannot be taken seriously. From the top of the main range, where crossed by the Moffat line, the distance to Chicago is about 1200 miles; at the lowest soft coal rates ever quoted this part of the freight alone would amount to about $4.00 per ton, and anyone familiar with anthracite mining and preparing, and Colorado conditions, knows it could not be put on cars at a profit at less than $3.00 per ton for the marketable sizes. Now, so low a coal rate as above cannot be expected, as the balance of the freight is east bound, so the coal carrying cars would have to return empty. It is probable that the rate would be not less than ½ cent per ton mile, which is but one-half the rate from Pennsylvania to Chicago. From the proposed Moffat mines to the top of the range the rate might be anywhere from $1.00 to $3.00. So if this anthracite deposit exists, and sufficient anthracite is obtained to more than supply the Colorado home demand, which I doubt, it is not at all probable that Colorado anthracite could be laid down in Chicago at less than $10.00 or $12.00 per ton. In recent years, anthracite from the Smith and Ruby mines mentioned above has occasionally reached Omaha when it has met the Pennsylvania anthracite on a parity, selling at from $10.00 to $11.00 per ton, but Omaha is 500 miles west of Chicago.

Therefore if the Chicago public desires a smokeless fuel at lower prices than anthracite, efforts must be made to utilize soft coal at her own doors by turning it into gas and domestic or fuel coke.

CLOSURE—BY MR. MERRIAM.

In answer to Mr. Finley's question, in regard to comparative quality of coke, below are given monthly averages of crushing strength tests on coke from the Trinidad district:

Location of Ovens.	Crushing strength in pounds per square inch.
Sopris	2,400
Elmoro	1,375
Starkville	1,375
Tobasco	1,100
Tercio	1,425
Segundo	1,820

This coke is bright and has metallic lustre and ring. In our own practice we use 48-hour coke exclusively at Pueblo blast furnaces, as we find the coke is not improved enough by the extra time to warrant making 72-hour coke, our only requirements being low percentages of sulphur and phosphorus and a crushing strength of not less than 1,200 pounds per square inch.

The geological conditions of the whole Rocky Mountain coal fields have been ably treated in "Mineral Resources of the United States" for 1892, by R. C. Hills, Geologist of The Colorado Fuel and Iron Co., and more recently and thoroughly on occount of latter developments by Mr. L. S. Storrs, Geologist of the Northern Pacific Railway, in the "Twenty-second annual report of the Geological Survey," part III, under the caption, "The Rocky Mountain Coal Fields." In this he says—"The coal fields of the Rocky Mountain region occupy a belt along the eastern base of the main range, extending southward from the Canadian boundary fully 1,000 miles, through Montana, Wyoming, Colorado, and New Mexico. The coal bearing formations are not continuous throughout this belt, but occupy about 60 per cent. of the distance. Another less extensive belt of coal fields occurs along the western base of the Rocky Mountain range in Wyoming, Utah, Colorado, and New Mexico. Between these two belts, in the Park region, are numerous isolated basins, in most of which the strata are so much disturbed that the coal is mined with difficulty," etc., etc. In this article Mr. Storrs gives two valuable maps showing the locations of all known fields and their general outlines.

The areas of coal deposits are given under two general heads for the different states, as follows:

	Anthracite, Bituminous, Lignite-bituminous coal, sq. miles.	Lignite coal square miles.
Montana	13,000	19,000
North Dakota		24,000
South Dakota	120	4,500
Wyoming	7,500	9,000
Utah	2,000	......
Colorado	18,100	......
New Mexico	2,890	......
Total	43,610	56,500

The lignite coal occurs in the plains areas and is the extension eastward of the mountain fields proper.

With regard to southern fields, Mr. Storrs gives the following, namely: Gallup, Mount Taylor, Carthage, Tejon, and Los Cerrillos. All of these are south and west of the Maxwell grant, and the field at Gallup on the A., T. & S. F. R. R. is extensively worked, coal being shipped as far west as Los Angeles, Cal. As has been stated, all of the coal, or nearly all, in the Rocky Mountain regions is contained in beds of the cretaceous age, and was originally lignite, and was greatly broken up by the forces which changed it to its present form, and it is only by dint of careful prospecting that workable beds of reasonably large areas are found; nevertheless, Mr. Storrs gives the average value at the mines of all Colorado coal in 1901 as being $1.12 per ton. Can any state do better?

Regarding the chemical analyses given in the body of the paper, they are average values as stated, and are for raw coal before washing. Below are given some analyses which I happen to have at hand:

Primero,	Fixed carbon	61.33
	Volatile matter	26.44
	Ash	12.23
	Total	100.00

Primero, fine slack screened through ¼-inch mesh.

Fixed carbon	58.70
Volatile matter	33.44
Ash	7.86
Total	100.00

Tercio,	Fixed carbon	56.44
	Volatile matter	32.80
	Ash	10.76
	Total	100.00

The reason Primero fine slack gives such low ash values is because the coal is much softer than the bony material which occurs with it in the seam.

CLXXXVI.

SEWAGE DISPOSAL IN IOWA.

Prof. A. Marston, M. W. S. E.

Read Oct. 7, 1903.

Iowa is everywhere known as preeminently an agricultural state. I recently heard the Governor of the commonwealth, in a public address, declare that nowhere else can be found so large a continuous tract of land having so small a percentage of waste area. Ninety-seven and one-half per cent of all the area inclosed within Iowa's boundaries is tillable land. According to the census of 1900 the value of her farms amounted to $1,834,345,546, and the state ranked first in the Union in the value of farm products. In a general way it is perhaps not too much to say that nearly all the important industries of the state depend very directly upon agriculture for either the supply or the demand which makes possible their existence.

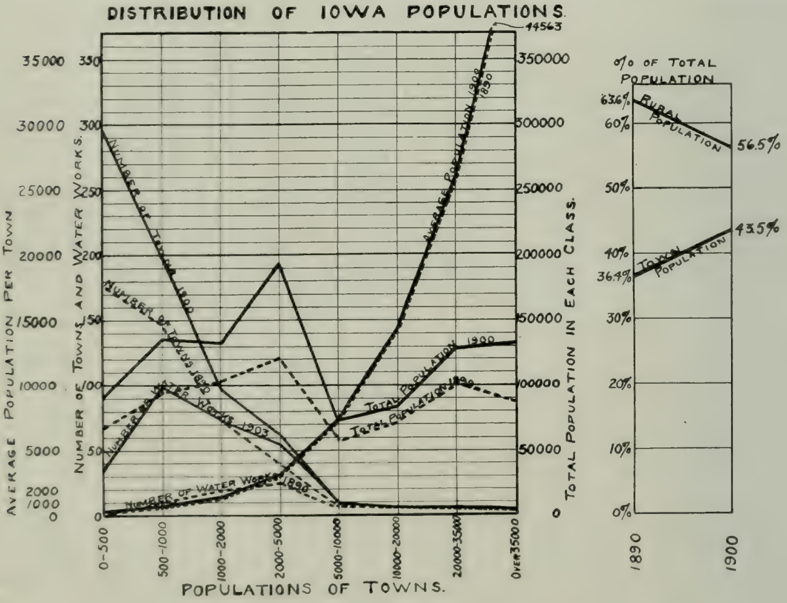

Fig. 1.

Diagram of City Populations and Improvements.

The fact that the state is preeminently agricultural must be fully taken into account in the study of any Iowa field of engineering, and at first thought it would seem that this preeminence of agriculture must seriously limit the field of engineering in the state. It may certainly be said, that properly within the scope of a paper on sewage disposal, will fall a careful study of the towns and cities of the state, which must depend so vitally and in so many ways upon the engineer, and which furnish the principal part of the field of sanitary engineering. In Fig. 1 are given for the years 1890 and 1900 the total number and the average size of Iowa cities arranged in eight classes according to size, together with the total population and the number of waterworks in the cities of each class. The percentages of total rural and total town populations are also shown for the same periods.

A glance at Fig. 1 will show that as regards her towns, Iowa is especially a state of small cities. Out of a total of 681 incorporated towns and cities, 657 have less than 5,000 population and the largest city in the state had only 62,139. About 57 per cent of the total town population is in places of less than 5,000 population. We are not however, to suppose that because the towns of the state are individually small in size that they are therefore of little importance. The diagram shows the remarkable fact that 43½ per cent of the total population of this preeminently agricultural state, live in incorporated towns and cities, and that this percentage rapidly increased during a decade in which agriculture was not declining but flourishing. Between 1890 and 1900 the farm values of Iowa increased 66½ per cent, and the annual value of farm products 130 per cent.

The fact is, that agriculture is becoming more and more a scientific pursuit. The successful farmer of today must be progressive and well informed, and consequently cannot live to himself so much alone, as in the past. He demands more and more the same comforts and conveniences of life as the resident of the city, and an increasingly large percentage of the total population must reside in cities to supply his wants. Thousands and thousands of Iowa farmers today have in their homes the telephone, daily free mail delivery, and furnace heat. A few already have waterworks, utilizing the farm wind mill. In a few years many will have modern plumbing in their homes.

It must be manifest that even the small cities of such a State muts demand the same modern conveniences of life as the residents of large cities. Very generally Iowa cities of 2,000 and more population are either building or agitating for the construction of pavements, while places of 1,000 and more are supplied with electric lights. Fig. 1 shows that only 31 towns out of 186 of over 1,000 population are still without waterworks, while even 36 towns of less than 50 population have waterworks systems. While the author's list of Iowa waterworks is not yet thoroughly checked, yet Fig. 1 shows a large field for the construction of sewers in Iowa, for it is not unreasonable to say that wherever a waterworks system is built, something in the way of sewerage will soon be called for. As a matter of fact Iowa has already entered upon and is now in the midst of an era of sewer construction which will probably be as remarkable as that of waterworks construction in the past.

One of the first and most serious problems to be solved by an Iowa town which wishes to build sewers is what to do with the sewage, for seldom can a river or large creek, as in the east, be found near at hand into which to discharge the sewage. It is true that a fringe of towns on the eastern boundary and a similar fringe along part of the western boundary utilize the Mississippi and the Missouri without regard to the health or sensibilities of St. Louis. A few places in the interior also, are located upon rivers properly so called. But the great majority of the streams into which the sewage can be discharged are small, and even though the drainage area be many square miles in extent, are liable to be nearly or entirely without water for months at a time in dry seasons. This, together with the growing necessity for utilizing the larger streams for water supplies, will make some method of sewage purification necessary sooner or later, in the great majority of cases.

Already several places have become involved in legal difficulties on account of disregard of the rights of others in this particular. Marion, Marshalltown, and Grinnell have been forced by such difficulties to build purification plants. The first named place has recently had a long standing suit decided against it by the supreme court, and Grinnell has a similar case pending. A judgment for damages has been obtained against the city of Boone, and the appealed case is yet before the courts.

As a result of the conditions which have been discussed above, the towns of the state are becoming educated to the necessity of providing for sewage disposal, and a beginning has already been made, as will appear from a description which will now be given of the plants constructed or under way.

The first complete sewage purification plant to be constructed in Iowa was the Iowa State College plant, at Ames, built in 1898. Prior to that time however, some attempts, more or less crude, had been made at a few places to better the condition of the raw sewage before discharging it into a stream. The author has obtained from various sources, information more or less imperfect, regarding several such cases.

Insane Asylum, Independence, Iowa. Information from a paper by the State Architect, H. Liebe, in Bulletin of Iowa Institutions, July, 1903, p. 393. "The disposition of the sewage from this institution was such as to deserve passing notice, for it had originally been attempted to dispose of it by sub-irrigation, but for some reason had proven a failure, and when the Board took charge, nothing visible of this remained except a huge brick basin with a dilapidated roof cover, into which the sewage flowed on the houseward side and out on the opposite end through a strainer, so that this chamber was simply an open cess-pool, with its accompaniment of foul emanations, whose presence were often decidedly perceptible in and about the institution during rainy periods, when the wind was in the east. After due consideration this was abandoned, and the sewage now flows unobstructed and discharges into the Wapsipinicon River about two miles east of the institution."

The date of construction of the above plant was about 1886. The tank was about 30 ft. x 15 ft. The population of the institution is about 1,100.

Girls' Industrial School, Mitchellville, Iowa. Mr. Liebe, in the paper above referred to, states that the sewers here discharged into a brick cess-pool 500 feet west of the Administration Building; the overflow by seepage finally reached a small creek. There was trouble from odors when the wind was in the west. Date of construction not known. Population about 200.

Penitentiary, Fort Madison, Iowa. Mr. Liebe, in the same paper, states that the sewer here discharged into "an ancient subterranean septic tank, from the opposite end of which it found an outlet to a passing creek." * * * "It was the custom to open the floodgate after a good rainfall" to clean out the tank. Population about 450. Date of construction, 1894; size, 12 ft.x12 ft.x50 ft. The tank is now abandoned.

Washington, Iowa. Information obtained by personal visit. Here in 1886 the city built at the outlet of its sewer a sewage tank about 35 feet long by 9 feet wide by 15 feet deep, the depth of sewage being about 8 feet. The walls are of rubble masonry about 14 inches thick, and the cover is of plank laid on railroad rails. The tank was purposely built in a stratum of coarse sand into which, about 18 inches below the level of the outlet, eight lines of 8-inch agricultural drain tile on each side of the tank extended about 30 feet, ending on each side against another line of 8 inch tile laid parallel with the tank, but with no direct communication. It was attempted in this way to secure filtration of the sewage. A 12-inch overflow pipe was also provided. At the time of the writer's visit, Aug. 25th, 1902, the tank was temporarily out of use, owing to a break in the sewer, but members of the city council asserted that the effluent was ordinarily quite clear and free from odor. The sewers are combined sewers and the sewage is probably considerably diluted with ground water. The population of the city in 1900 was 4,255, only a small part of whom have sewerage connections.

New Hampton, Iowa. From a recent letter from M. Tschirgi, Jr., Civil Engineer, Dubuque, Iowa, the following extract is made: "Some four or five years ago, the town of New Hampton, Iowa, constructed some sanitary sewers and had the outlet in a low marshy field, from which a ditch led away storm water. At the outlet a closed brick tank, probably 10 feet by 10 feet was constructed, into which the sewage emptied, and the overflow was carried some distance in an open wooden box to the ditch mentioned. I examined the effluent the other day and found that after flowing some distance it was apparently free from odor and quite clear, causing no apparent nuisance. The work was designed, I believe, by Boynton & Warriner of Cedar Rapids at that time." Population in 1900 was 2,339.

There doubtless may have been other attempts to better the sewage along the above lines of which the author has not learned. The plant next to be described was the first complete purification plant, however, to be built in the State.

Iowa State College, Ames, Iowa. The plant here was designed by the author in 1895 and built in 1898. For a full description see the Proceedings of the Iowa Engineering Society, 1900, and Engineering Record, Feb. 17, 1900. For description and extended chemical and bacterial analyses see Bulletins 1, 2, 3, 4, and 5, on Sewage Disposal, of the Division of Engineering of the Iowa State College.

Briefly, the plant consists of a septic tank 22 feet by 54 feet by 4 feet deep, and of two intermittent sand filters, each 55 feet by 150 feet by 4 feet deep. The tank has brick walls and a wooden cover and contains about 23,500 gallons. A compartment containing about 3,500 gallons is partitioned off at the inlet end for a sediment chamber and is emptied out at intervals of six weeks to four months. About four or five loads of dried sludge are obtained at each cleaning, which is used as fertilizer on the college farm. An 8-inch Miller siphon applies the sewage automatically to the filter beds in doses of about 22,500 gallons. In operation the surface of the filters is loosened at intervals of one to two months and in winter the beds are furrowed. In Fig. 2, reproduced from Proceedings of Iowa Engineering Society, 1901, the beds are shown in operation in severe winter weather. Only a few loads of dirty material have been removed from the filters in five years' operation.

There is not as much odor around the plant as around well kept pig pens near by, and residence lots have recently been laid out within 450 feet. The effluent is at all times as clear, sparkling, and odorless as spring water. The plant is successfully operated winter and summer. The present flow of sewage is about 40,000 gallons per day, coming from a student and faculty population of about 1,350, of whom perhaps 250 are tributary to the sewers throughout the twenty-four hours, the remainder using them by day only. Several thousand gallons from the college dairy are also included. Since August 28th, 1903, this entire flow has been successfully filtered by one bed alone, in an experiment now under way, giving a rate of 200,000 gallons per acre per day. The detailed chemical and bacterial analyses for 1901, the last year during which frequent analyses were made, are shown in Fig. 3. It will be seen that the purification is about 95 per cent., as regards both albuminoid ammonia and oxygen consumed, being a little less in winter than in summer. The bacterial purification is 98 to 99.9 per cent. It will be interesting to note that in the fall of 1900 the college was visited by a severe epidemic of typhoid fever, contracted from the milk supply, during which a hospital was established treating about fifty patients. Here large quantities of disinfectants were used, which were also applied directly to all the sewers. No appreciable bad effect on the sewage disposal plant could be detected, however. The amount of sewage treated was at the same time abnormally high.

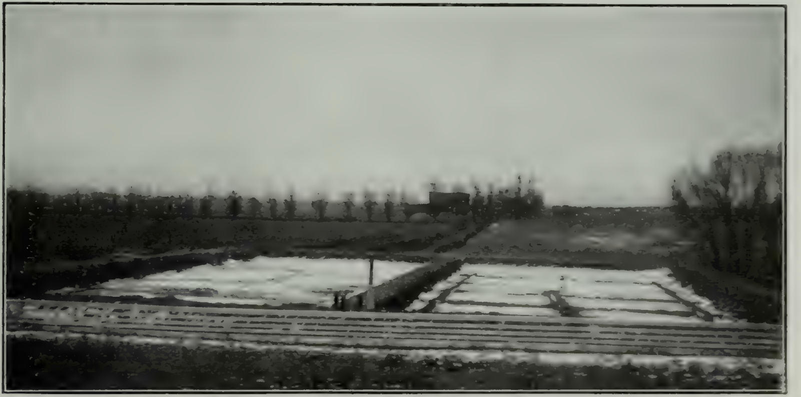

Fig. 2.
Iowa State College Sewage Filters in Winter.

This plant, being so succeessful and so prominently located, has exerted a great influence in favor of sewage purification in Iowa.

It cost only $2,500, but could not now be duplicated for less than $3,500 to $4,000.

Marion, Iowa. Population, 4,102. As already stated, the construction of this plant was forced by legal proceedings resulting from the discharge of the city sewage into a small creek. It was

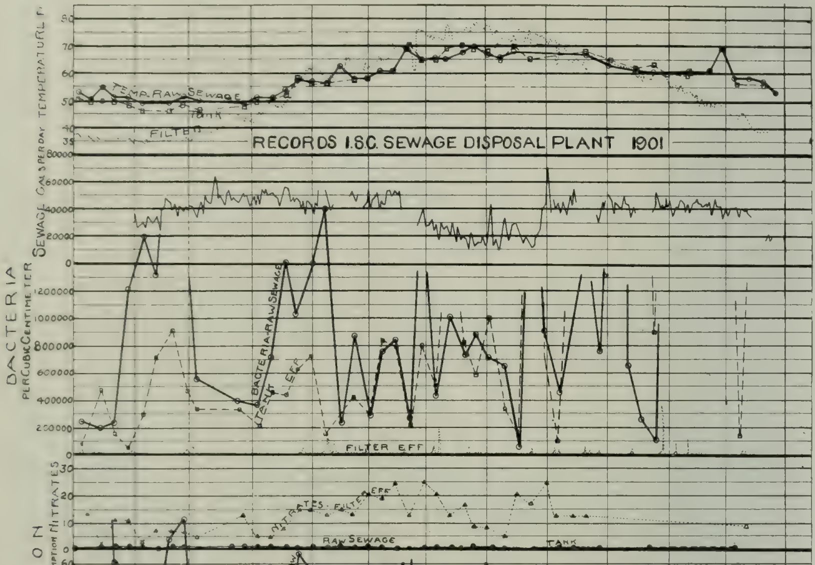

Fig. 3.
Diagram of Operation, Sewage Plant.

built in 1899, and was designed by Snow & Barbour, the construction being under the charge of the engineering firm of Wardle & Yeager, of Cedar Rapids. As designed, the sewage was to be first passed through a septic tank and then filtered through cinder contact beds, but only the septic tank has been constructed. This tank is 62 ft. 9 in. long by 37 ft. 3 in. wide inside, and contains sewage to a depth of 8 feet. The top is arched over with concrete masonry resting on brick piers and arches and is covered with earth. The capacity is about 140,000 gallons. The sewage enters at one end through three submerged inlets and is removed at the other end through a slotted pipe placed about three feet below the water line. From the slotted pipe it passes up and into a masonry channel which conveys it to a manhole where it is aerated by a drop of several feet. The details of the tank are shown in Fig. 4.

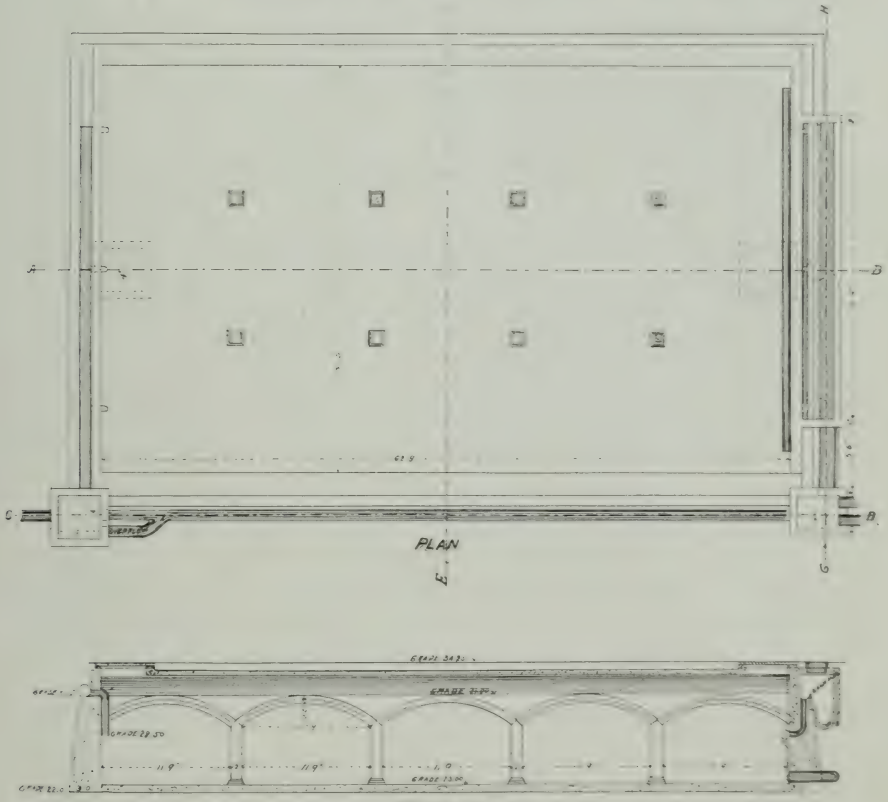
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Fig. 4.
Main Septic Tank.

The cost of the plant has been given as $10,000, but the author understands this to include the outlet sewer, and that the tank cost $5,000 or $6,000.

The author has personally visited this plant twice and each time found it giving entire satisfaction. There was no noticeable odor around the plant, although the effluent from the tank passes directly into a shallow pond, of area about one acre. The effluent, although not perfectly clear, nor entirely free from odor, was yet very good in appearance, and produced no visible pollution in the small stream into which it is finally discharged. The ditch leading from the pond to the creek had a grayish growth on the bottom and sides, which was not in offensive amount.

At the time of the second visit the tank had been in use about two years without cleaning. The effluent did not appear to be quite so good as at the first visit. The tank was operated at least 2½ years and perhaps longer before it was cleaned.

Recently the author sent a representative to make a third inspection of the plant and take samples for analysis. He reports that the tank at the time of his visit was empty and out of use. The mayor of the city makes the following statement regarding the cause: "At the time your man was here taking samples the tank was being flushed out on account of two conductor pipes on the inside of the tank having become stopped up with foreign substances. These pipes we find are too small and we have been having some trouble with them."

The author has no reliable measurement of the rate of flow through the tank. The population of the city in 1900 was 4,102.

Marshalltown, Iowa. Population, 11,544. The construction of this plant also, was forced by legal difficulties in which the city became involved from the discharge of the sewage into the Iowa River. This stream is of size sufficient to prevent a nuisance when nothing but the city sewage proper is discharged into it, but trouble came from the manufacturing wastes from the glucose factory, and which are in volume about twice that of the city sewage proper, and which are several times stronger than the city sewage. The discharge of these wastes and the city sewage into the Iowa River, at times of low water, killed fish and in many ways created a nuisance for miles below. Complaint was especially great at Tama, a considerable town 16 miles down stream from Marshalltown. There the river water was led through a mill race into an ice pond located in the city. Injunction suits left Marshalltown the alternatives of constructing a sewage disposal plant or shutting down its principal manufacturing industry, and construction was begun in 1900.

The total volume of sewage to be treated was about 1,500,000 to 2,000,000 gallons, of which 1,000,000 to 1,500,000 was from the glucose works. In the glucose sewage the polluting material consists mainly of particles of starch and gluten, so very fine that they escaped all means yet invented for saving them for commercial use. The strength of this sewage is shown by analyses to be several times as great as that of ordinary sewage.

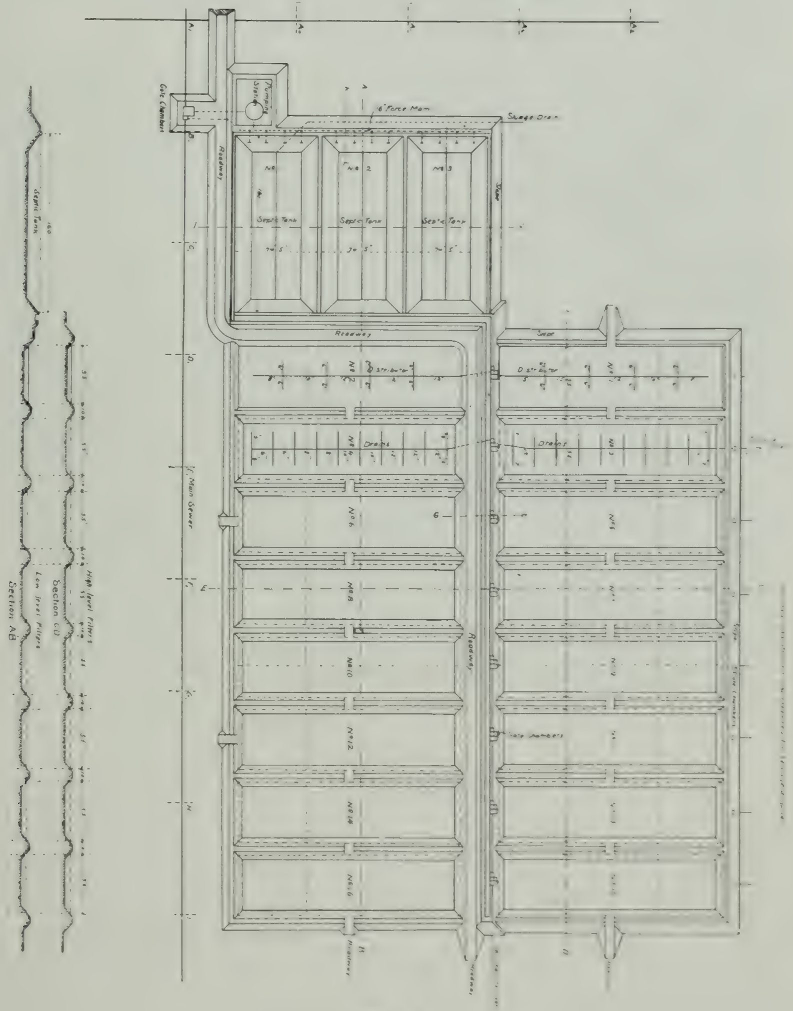


Fig. 5.
Plan of Marshalltown, Iowa, Plant

Although the author was employed by the city to make preliminary investigations, and later to act as consulting engineer for construction, the full credit and responsibility for the Marshalltown plans fall to Mr. George S. Pierson, M. Am. Soc. C. E., who prepared them. In fact the author advised the city not to undertake the construction of a full sized plant to treat this new kind of sewage until it had first experimented on a smaller scale. The general layout of the plant is shown in Fig. 5. The sewage is received first in a pumping station, where it is lifted about 14 feet by two 10-inch vertical centrifugal pumps, driven by direct connected electric motors. Power is brought from the city waterworks plant, 2 ½ miles away. The pump house is circular, of 16 feet inside diameter. The sewage passes from it into three open septic tanks side by side, each 160 feet by 74 feet 5 inches at the water line, built in earth embankment lined with 6 inches of concrete. The sewage is about 10 feet deep and the combined capacity of the three tanks is about 2,000,000 gallons.

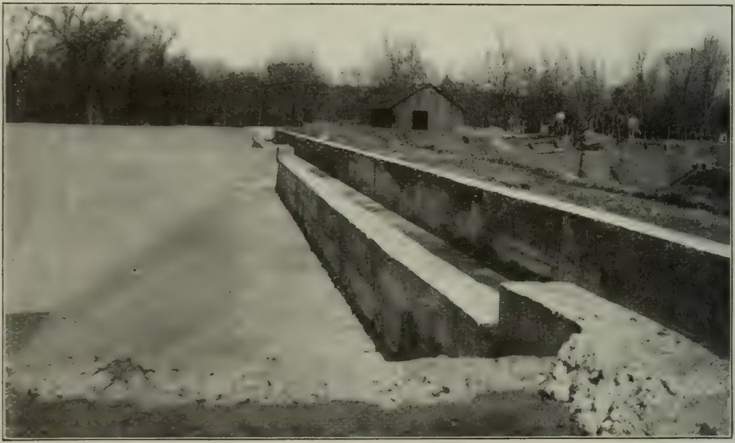


Fig. 6.
Outlet end of Marshalltown Septic Tank.

From the septic tanks a concrete sewage carrier leads to 12 cinder contact beds, each 200 ft. by 55 ft. by 3 ft., arranged in two levels so that they can be used for double or single contact as desired. These beds are in earth excavations and embankments, not enclosed in masonry. The flow of sewage is controlled by gates operated by hand. In Figs. 6, 7 and 8 views of the construction of the plant are shown.

Unfortunately for engineers interested in ascertaining what results can be obtained in treating the difficult sewage at Marshalltown in the way proposed, the plant is not yet in operation and there is no good prospect of its use in the immediate future. The pumping station, the septic tank and two of the twelve filters are completed, and most of the grading for the other filters has been done, the total expense to date having been, the author understands, about $50,000. The Glucose Factory has been closed down now about three years, and as long as it is not running, there is little likelihood of the city putting the disposal plant in operation.

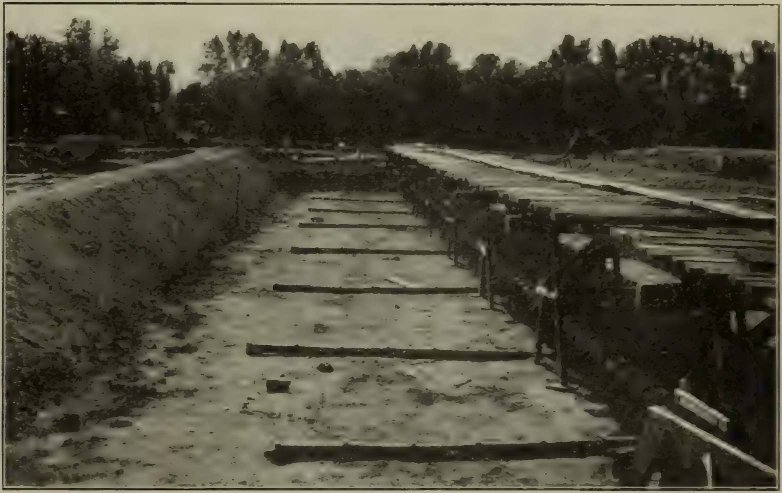


Fig. 7.
Marshalltown Filter—Ready for Cinder Filling.

Fig. 8.
Marshalltown, Iowa—Sewage Filter Completed.

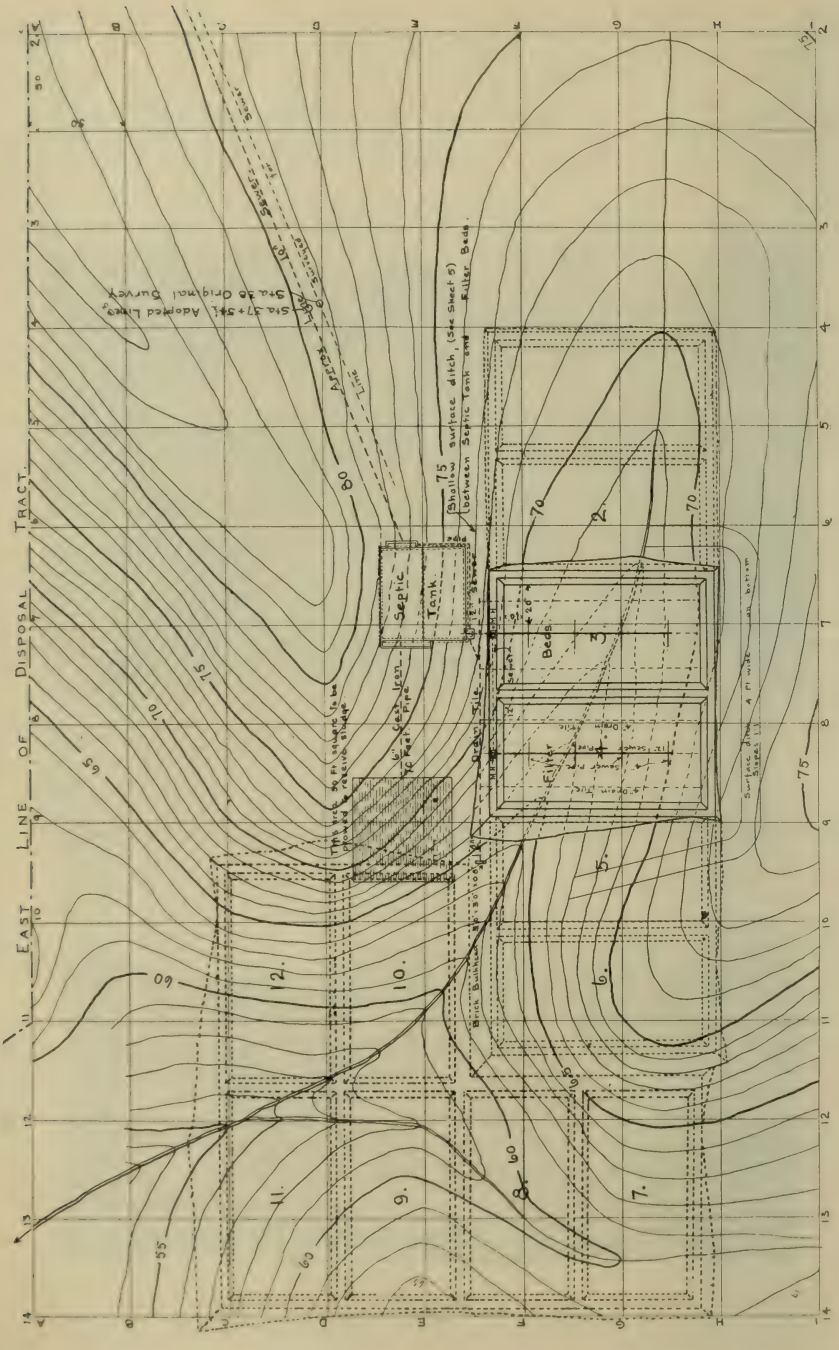

EAST LINE OF DISPOSAL TRACT.
12" Sewer for Lake Line
Sewer
Sta 37+34½ Adopted Lines, Sta 38 Original Survey
Adopted Line
Shallow surface ditch, (See Sheet 5) between Septic Tank and Filter Beds.
Septic Tank.
12" Sewer
6" Cast Iron Pipe 16 feet
This area 30 ft square to be plowed to receive sludge.
Drain Tile
Brick Bulkhead
Filter Beds
Surface ditch 4 ft wide on bottom Slopes 1:1
1.
2.
3.
5.
6.
7.
8.
9.
10.
11.
12.
55
60
65
70
75
80
A
B
C
D
E
F
G
H
I
2
3
4
5
6
7
8
9
10
11
12
13
14

Fig. 9.
General Plan of Sewage Plant—Spirit Lake, Iowa.

Spirit Lake, Iowa. Population, 1219. This plant was constructed in 1901. The details are shown fully in Figs. 10, 11 and 12. Briefly, the plant consists of a septic tank 43 ft. by 45 ft. by 4 ft., with brick walls and a wooden cover and containing about 40,000 gallons of sewage, in three compartments. One of these compartments, containing about 20,000 gallons, serves as a dosing chamber, and discharges automatically when full, by means of an 8-inch Miller siphon, upon the surface of two sand filter beds, each 100 ft. by 50 ft. by 3 ft. 6 in. The whole plant, which was designed by the author, is quite similar to the State College plant. It cost $3,200.

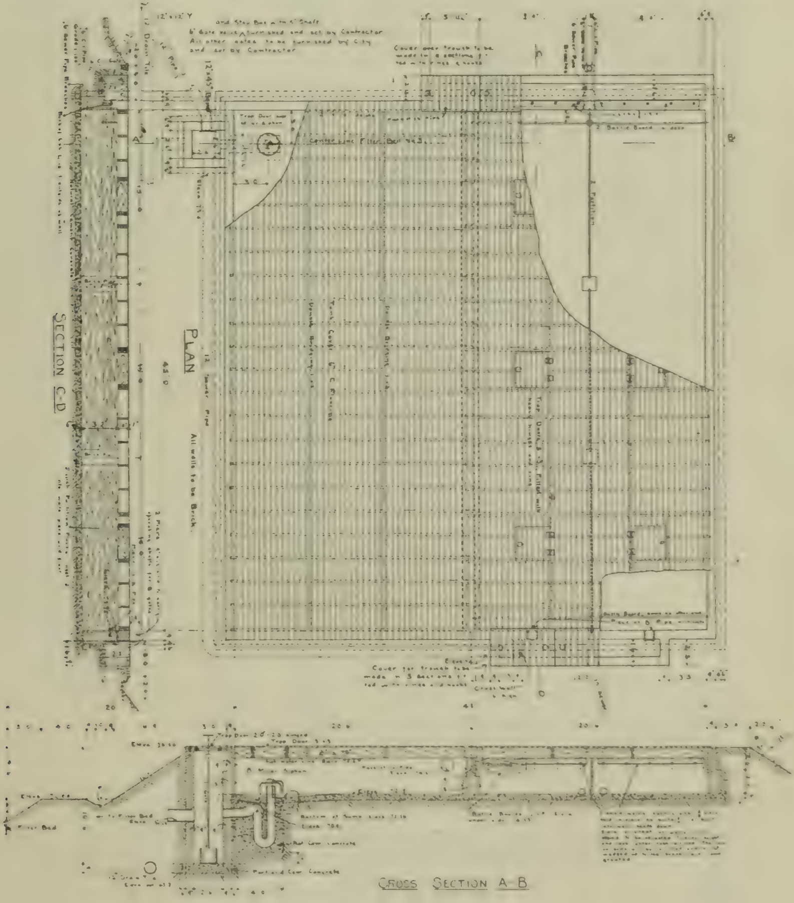


Fig. 10.
Details Septic Tank—Spirit Lake, Iowa.

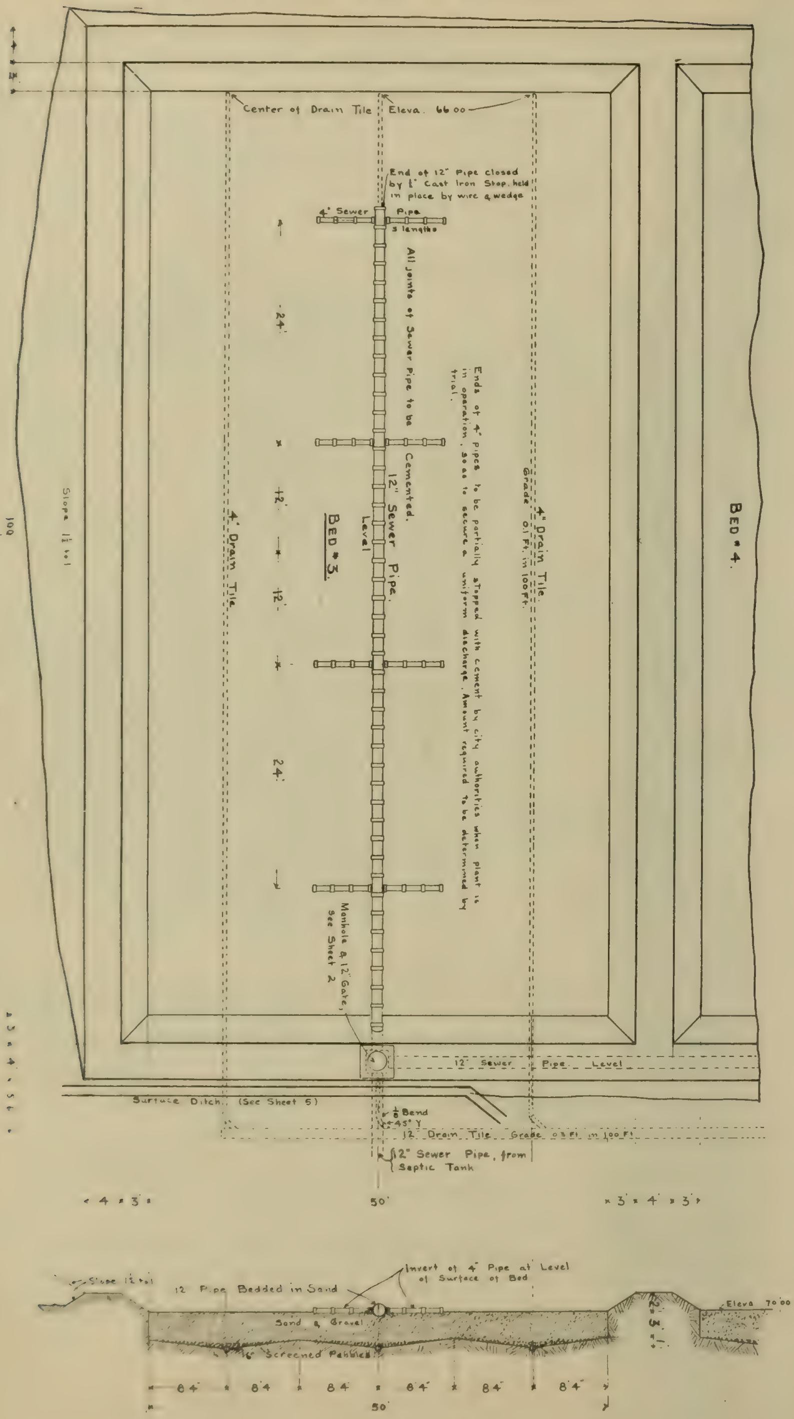

Center of Drain Tile
Eleva. 66.00
End of 12" Pipe closed by 1" Cast Iron Stop, held in place by wire & wedge
4" Sewer Pipe
3 lengths
All joints of Sewer Pipe to be Cemented.
12" Sewer Pipe.
Level
BED #3.
Ends of 4" pipes to be partially stopped with cement by city authorities when plant is in operation, so as to secure a uniform discharge. Amount required to be determined by trial.
4" Drain Tile.
Grade 0.1 Ft. in 100 Ft.
4" Drain Tile.
BED #4.
Slope 1½ to 1
100
24'
12'
12'
24'
Manhole & 12" Gate, See Sheet 2
12" Sewer Pipe. Level
Surface Ditch. (See Sheet 5)
⅛ Bend
45° Y
12" Drain Tile Grade 0.3 Ft. in 100 Ft.
12" Sewer Pipe, from Septic Tank
4 3
50'
3' 4' 3'
3 4 5 6
Slope 1½ to 1
12" Pipe Bedded in Sand
Invert of 4" Pipe at Level of Surface of Bed
Eleva. 70.00
Sand & Gravel
6" Screened Pebbles
2'
3'
1'
8'4"
8'4"
8'4"
8'4"
8'4"
8'4"
50'

Fig. 11.
Filter Bed at Spirit Lake, Iowa.

The volume of sewage treated at the time of a visit by the author in August, 1902, was about 18,000 gallons per day. At the time of a similar visit in August, 1903, the superintendent stated that the dosing chamber empties two or three times per day, making 40,000 to 50,000 gallons per twenty-four hours. Although a hotel and a few houses are connected with the sewer, the sewage is almost wholly composed of very thick and strong wastes

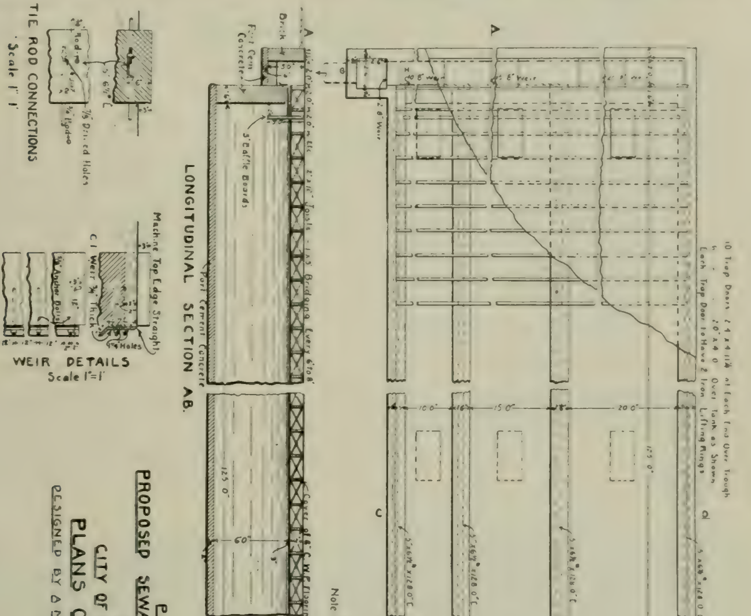


Fig. 12.
Plan of Septic Tank, Grinnell, Iowa.

from a butter renovating factory. Chemical analyses, to be given later, show it to be several times as strong as ordinary sewage, and the sewage is really much worse than even the analyses would indicate, for the polluting material is mainly casein (extracted from the butter renovated), a material which it is very difficult to decompose. Two analyses gave respectively 7,120 and 12,400 parts per 1,000,000 of solids on evaporation, which should be compared with 750 to 3,000 in ordinary sewage.

Owing to various reasons the city has not yet operated the plant properly, or according to instructions. The septic tank has not yet been cleaned out, although the solids, from the renovation factory, accumulate in it in large quantities, not decomposing to any large extent as do the solids in ordinary sewage. At Spirit Lake the tank should probably be emptied every three months, whereas it has now been let go two years, and is long since badly clogged. The beds also are not given as much attention as they need. On account of the excess of non-decomposable solid matter, the beds require loosening up much oftener than with regular sewage, and also require more cleaning. The city has not yet made any attempt to use the plant in winter, but agrees to operate it this coming winter. For this, one bed will be covered with removable boards.

On account of the peculiar nature of the sewage, this plant is of especial interest to the author. He is not satisfied with the results yet obtained, although the contamination of the lake is prevented, which was the object of the plant. The author believes that better results can be secured with proper handling of the plant. Little nitrification, and at times none, is yet established, and considerable free ammonia is left in the effluent, although the removal of oxygen consumed is extraordinarily high. The effluent is not entirely clear and has considerable odor when held close to the nose. There is a slight grayish growth on the invert of the outlet drain. There is considerable more odor around the tank than should be the case with ordinary sewage, although when fairly well cared for the odor around the entire plant is not noticeable at any considerable distance away.

Grinnell, Iowa. Population, 3,860. Here the outlet of the sewer system, which was built in 1895, is into a small creek with little or no flow in dry seasons. Although this flows only through meadows and cultivated fields complaint from the land owners below increased until in 1902 the city was confronted with the prospect of a suit for an injunction against further discharge into the creek, and one farmer owning land two or three miles below the sewer outlet brought suit for damages already incurred. This suit is still pending before the supreme court. Under these circumstances the city decided to build a purification plant. Funds were limited, and in wet seasons the sewage is comparatively weak, so, bearing the favorable experience of Marion in mind, it was decided to build only a septic tank at first, leaving filters to be added later when found necessary.

Measurements of the flow of sewage in the spring of 1901 and the summer of 1902 gave 400,000 to 450,000 gallons, and this flow continued from the opening of the plant in December 1902 to July 15, 1903, when it suddenly decreased to about 100,000 gallons, which is a little greater than the water consumption of the city, and is probably about the normal flow in dry seasons. The great fluctuation is due to the infiltration of ground water through the joints of the sewers. The strength of the sewage fluctuates correspondingly, and as about 2,000 to 2,500 people actually use the sewers the sewage varies from one-half to twice the strength of ordinary sewage. The storm water from a few blocks also discharges into the sewers, and a flow through the septic tank as high as 2,500,000 gallons per day for several hours has been observed.

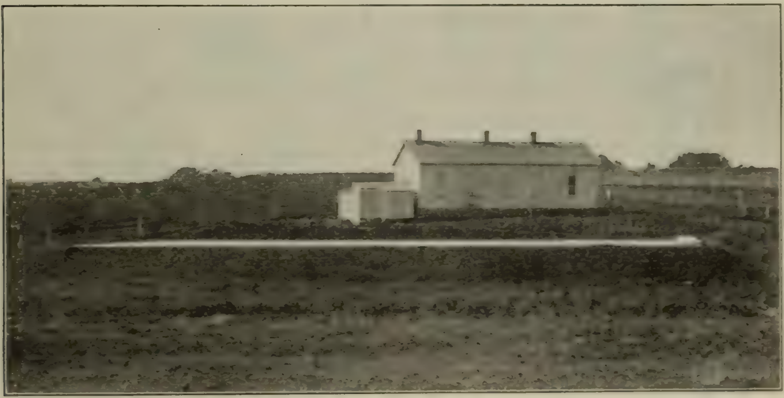
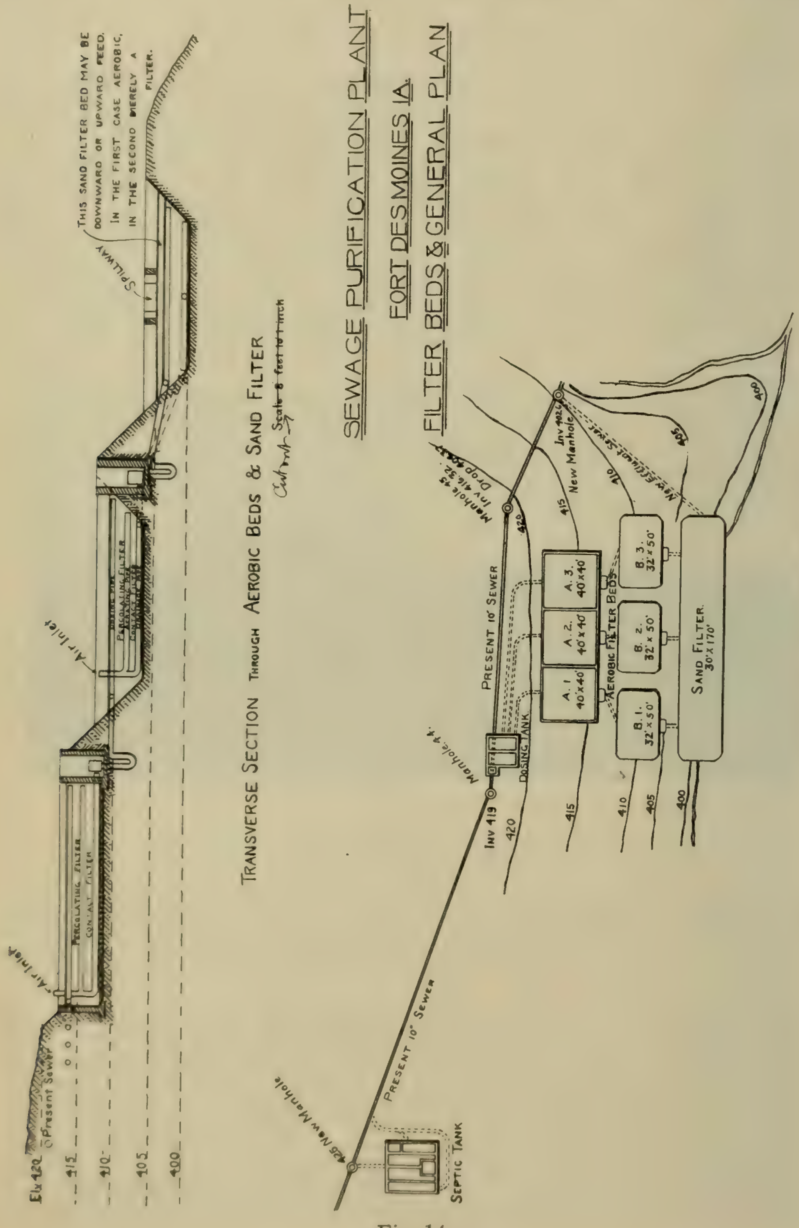


Fig. 13.

Septic Tank, Grinnell, Iowa—Capacity, 252,000 Gallons—Pest House 20 Feet Distant.

To provide for these great fluctuations the tank was designed in three compartments, of different sizes, which can be used singly or in any combination. The details of the tank are shown in Fig. 13 which is reproduced from the "Iowa Engineer." It is built of concrete with a wooden cover. The outside dimensions are 51 feet by 134 feet, the depth of sewage is 6 feet, and the tank holds about 252,000 gallons. The sewage enters a masonry trough extending across one end, from which nine six-inch valves open into the tank. Occasionally some obstruction has to be removed from one or more of these valves, and in later designs the



General Plan—Fort Des Moines, Iowa.

Fig. 14.

author modifies this detail. The sewage, as it enters the tank, is deflected downwards and spread out by a baffle board extending 2 feet 6 inch below the surface. At the opposite end it passes under a similar baffle board, then up, and is discharged over long cast iron weirs. Some bacterial growth forms on these weirs, but not enough to interfere injuriously with the work of the tank. After flowing over the long weirs the effluent passes over a smaller measuring weir and is aerated by a drop of several feet in a manhole, from which it discharges into the creek.

With the large rate of flow noted above as obtaining until about July 15, 1903, the effluent of the tank was nearly, though not quite clear, had little odor, and created no nuisance when discharged into the creek, although it probably equalled or exceeded in volume the whole natural flow of the creek. With the sudden drop of the flow from over 400,000 to 100,000 gallons per day, and the corresponding increase of strength, the results obtained were not nearly so good. The 20 foot compartment was then shut off, leaving a tank capacity of about 140,000 gallons in use, and the sewage soon increased to about 180,000 gallons per day. Under these conditions the quality of the effluent improved, though it is still not equal to that obtained at first. It was at this time that the sample for the analysis given later was taken.

Very little sediment has yet been deposited in the Grinnell tank and a scum has formed over only part of the surface. There is practically no odor about the tank. Fig. 14 is prepared from a photograph and shows a pest house, one corner of which is located within 15 or 20 feet of the tank, and which on at least two occasions has been used without complaint since the tank has been in use, although originally it was intended to move the pest house to another site.

The cost of the Grinnell tank was $6,760.

The next three plants to be described were all built by the Cameron Septic Tank Company of Chicago for the Iowa Board of Control of State Institutions. They are all strictly along the well known lines of the English septic tank installations. The tanks are built and arched over with concrete, covered with earth, and provided with grit chambers and slotted pipes for effluent and sludge removal. Cinder contact beds inclosed in concrete are used for filtration. Single contact is used. The regular Cameron Automatic Alternating Gear is employed, in which the flow and distribution of sewage are controlled by valves actuated by tilting buckets. Further details of the plants, taken from the contract are given below:

Soldiers' Orphans' Home, Davenport, Iowa. Population about 485. Contract capacity, 25,000 gallons daily. Also guaranteed for sewage of 800 people and all the domestic animals of the institution, Grit chamber, 2 feet 6 inches by 5 feet by 2 feet 6 inches deep below the water line. Septic tank, 50 feet by 10 feet by 6 feet below the spring line. The capacity is about 22,500 gallons. Effluent chamber, 2 feet by 5 feet by 3 feet deep below the water line. Four contact beds, each 24 feet by 13 feet 6 inches, containing 4 feet of cinders. Rate of filtration 839,000 gallons per acre per day for 25,000 gallons of sewage. Contract price, $4,450.

Industrial School for Girls, Mitchellville, Iowa. Population about 200. Contract capacity, 12,500 gallons daily. Also guaranteed for sewage of 400 people and all of the domestic animals of the institution. Grit chamber, 2 feet 6 inches by 4 feet by 2 feet 6 inches deep below the water line. Septic tank 36 feet 6 inches by 8 feet by 6 feet below the spring line. The capacity is about 13,000 gallons. Effluent chamber, 2 feet by 5 feet by 3 feet deep below the water line. Three contact beds each 15 feet by 11 feet containing 4 feet of cinders. Rate of filtration, 1,100,000 gallons per acre per day for 12,500 gallons of sewage. Contract price $2,625. The Superintendent of the School states that the actual flow of sewage is 5,000 gallons per day and that this is sometimes increased by rain water to considerably beyond the 12,500 gallons per day.

Iowa Hospital for the Insane, Mt. Pleasant, Iowa. Population about 1,065. Contract capacity, 70,000 gallons per day. Also guaranteed for sewage of 1,250 people and all the domestic animals of the institution. Grit chamber, 3 feet by 8 feet by 2 feet 6 inches deep below the water line. Septic tank, 78 feet by 14 feet by 7 feet 6 inches deep below the spring line. The capacity is about 61,000 gallons. Effluent chamber, 2 feet by 5 feet by 5 feet deep below the spring line. Four contact beds each 38 feet by 24 feet containing 4 feet of cinders. Rate of filtration, 836,000 gallons per acre per day for 70,000 gallons of sewage. Contract price, $7,250. The author measured one day's actual flow of sewage, Aug. 22, 1901, to be 75,000 gallons.

For all three of these plants the contracts guaranteed, among several other things, that there shall be no breakdowns and "that there shall be no possibility that the septic tank shall become a nuisance; that in all cases the effluent which passes from the plant shall be odorless, colorless, free from nuisance and unobjectionable in all respects."

The author is informed that the plants are not entirely satisfactory to the Iowa Board of Control and that it has withheld payment of all but a small part of the purchase price, except at Mitchellville, where the least complaint is made, "the remainder being held to secure the performance of the guaranties of the contract."

The following statement regarding the working of the plants has been secured from the Board of Control:

"As to the working of these plants, we can say they have not been wholly satisfactory as yet. Mr. Wyllie, of the tank company, admits that the matter used for filling the contact beds at Davenport, that is, screened cinders, is not satisfactory and will have to be replaced with something else. The plant at Mt. Pleasant has thus far been a complete failure; the one at Mitchellville has done fairly well, but is not satisfactory. We are inclined to think that cinders are not proper filling, at least not cinders of Iowa coal. You will notice that the system at Mitchellville has but three contact beds, making it necessary for some one to change the gearing once a week. The systems at Davenport and Mt. Pleasant have four contact beds, and the shifting of the flow from the different contact beds is strictly automatic, and the gearing works well."

In a letter from another source regarding the Mt. Pleasant plant the statement is made that "there has been continually a strong odor of hydrogen sulphide, which is especially objectionable when carried by the wind toward the main building." The same letter also states that the trouble was attributed to the use of chloride of lime disinfectants, though this was discontinued without apparent improvement, and that the automatic gear had broken down once.

On the other hand the author has the following statement from Mr. Wyllie, of the Cameron Septic Tank Company:

"In regard to the plants we have installed at Mt. Pleasant, Davenport, and Mitchellville, we have had exceptional conditions to deal with, which have taken time to provide for, and which even now have not been entirely removed, so that any chemical analyses you have made of the effluent from these plants cannot be considered conclusive evidence of their efficiency. The difficulties referred to are more particularly described in a paper I prepared for a recent meeting of Superintendents of Iowa Institutions, copy of which I enclose for your information."

In the paper above referred to Mr. Wyllie states in substance that the sewage of public institutions, like asylums, homes, and colleges, is especially difficult to treat, being stronger, fresher on account of the short distance, containing more soap and fat and being more liable to trouble from disinfectants. He instances the use of chloride of lime at Mt. Pleasant, and states that it not only held bacterial action in check, but also set free chlorine gas which ate away parts of the alternating gear. He further says that the plant had to neutralize itself after the disinfectant was stopped, requiring time. In the case of institution sewage the quality varies more than city sewage from hour to hour through the day. For example the kitchen wastes all come at one time.

The writer personally visited the Mitchellville plant July 11, 1903, There was no objectionable odor around the plant. While it was true that the effluent was not perfectly odorless nor clear, having in it numerous fine black particles which gave it a darkish color, yet it caused absolutely no nuisance when discharged into a small creek. The Superintendent stated that at times the effluent was clearer than at the time of the visit, and that at other times there was more odor about the plant.

Rockwell City, Iowa. Population, 1,222. A letter from M. Tschirgi, Jr., C. E., of Dubuque, describes the plant built at this place as follows: "Will state that the disposal plant referred to at Rockwell City is a small affair, costing about $600, a septic tank, about 12 feet by 20 feet, and filter bed, 30 feet by 50 feet, constituting the plant. For some years a very small amount of sewage will have to be treated, the principal amount from a creamery. The cinders used for filtering were not obtainable until recently."

Private Plant, Clinton, Iowa. The Iowa Engineering Company, of Clinton, write the author as follows:

"We have in operation a tank with bacteria beds and effluent discharged in sub-soil drains, on private grounds at Clinton, Iowa. Capacity, 7,500 gallons per twenty-four hours. It is successful."

Fort Des Moines, near Des Moines, Iowa. The plant at this place, shown in Figs. 15 and 16, is now under construction. It is located at the new army post not yet completed, and is guaranteed to give a high degree of purification when caring for the sewage of a garrison of 1,200. The sewage is to be received first in a closed septic tank, of about 71,000 gallons capacity, built of concrete and divided into compartments as shown. From this it will pass to a dosing chamber, holding about 10,000 gallons, and then to six contact beds, each containing 1,600 square feet, arranged for double contact. The three high level beds are enclosed in masonry, while the three lower are in earth. The flow of sewage will be controlled by Miller alternating and timed siphons. After passing through the double contact beds the sewage will finally be filtered through a sand filter 30 feet by 170 feet. At 75 gallons per capita, or 90,000 gallons per day for 1,200 men, the rate of filtration will be 1,810,000 gallons per acre per day for the contact beds, and 770,000 gallons per acre per day for the sand filter. The plant was designed and is being built by the Municipal Engineering Company of New York. The contract price is $20,670.

Additional Proposed Plants. The Iowa Engineering Company report that they have planned for septic tanks for Atlantic,

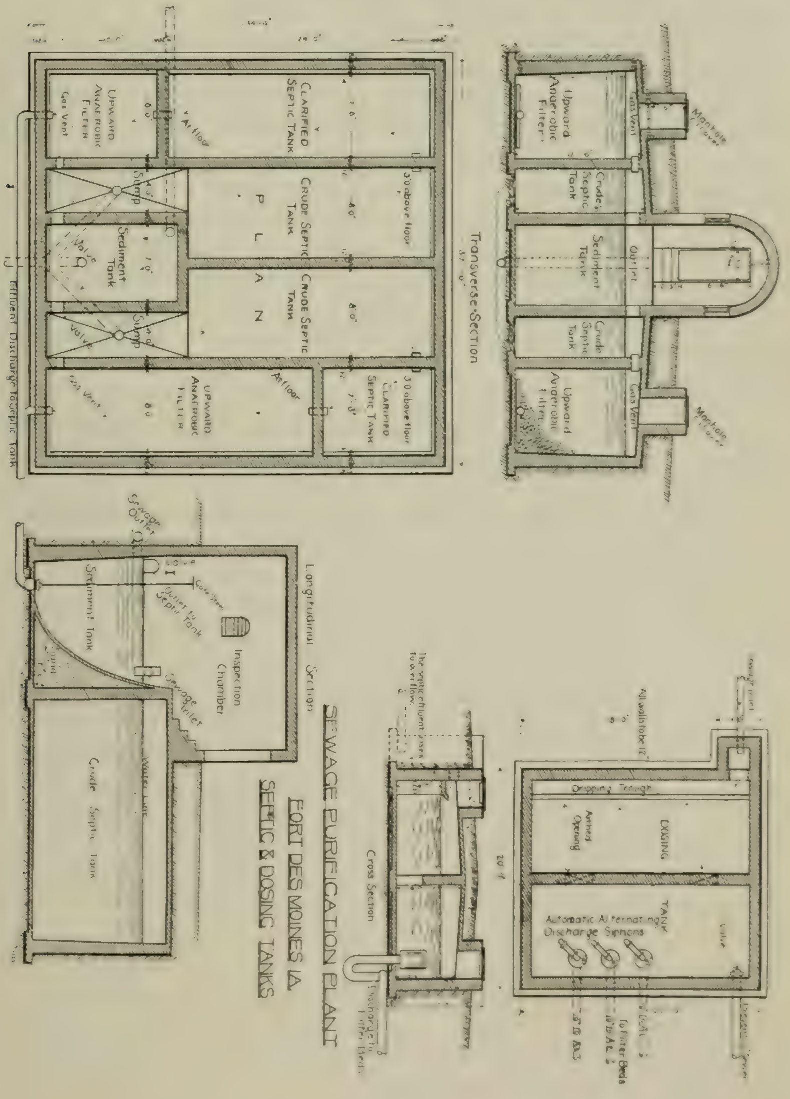


Fig. 15.
Details of Septic Tank—Fort Des Moines, Iowa.

Sigourney and Nashua, and septic tank and sand or cinder filters for Oskaloosa and Centerville, with what prospects of immediate construction the author has been unable to learn. Mr. Tschirgi reports that he has planned a plant similar to the one at Rockwell City for Hampton. The writer has prepared plans for closed septic tanks, entirely of concrete, the effluent to be treated by sand filters, for the cities of Ames* and Knoxville. The first named place has advertised for bids, and at Knoxville also it is proposed to go ahead at once with construction.

Before closing the descriptions of Iowa Sewage Disposal plants mention should be made of the experimental work at the Iowa State College, at Ames. This work was started in 1898, by keeping scientific records of the working of the college plant. Representatives of the college also visit other plants located in the state, and endeavor to keep track of their working and to make occasional analyses. At the present time an experiment is under way on the purification of creamery sewage, which is a problem confronting many communities in the state. An experimental septic tank, with three compartments in which different rates of flow are maintained, has been in successful operation since last spring. The college creamery sewage, when mixed with the other sewage of the institution, causes no apparent trouble in the full sized plant. Treated by itself in the small plant it is more difficult to handle, and though a vigorous septic action is established there is more odor about the small tank than about the large tank treating ordinary sewage. Filters are now to be added, and in general may be considered necessary for properly purifying creamery sewage. Another experiment just being started at the college is with a very small inexpensive plant for a private residence. The information obtained from the college sewage disposal investigations is published from time to time in the form of bulletins.

The following table contains the results of chemical analyses made of samples taken at the principal Iowa sewage disposal plants. All of the chemical analyses have been made by Professor J. B. Weems, and all the bacterial by Professor L. H. Pammel, both of the Iowa State College. For the State College plant only the general results for 1901 are presented, but these may be considered typical of the work of the plant. At Marion only a single sample was taken, which therefore, in the case of the raw sewage, represents only the flow during the few minutes during which it was being taken. From the other outside plants composite samples, each made by mixing hourly portions taken for twenty-four hours, were taken, except that in the case of the first sample at Mt. Pleasant the intervals were two hours. The samples were shipped to the college without the use of preservatives.

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* Since this paper was written, the Ames plant has been put under construction, and is now (Dec. 7, 1903) about one-third completed. It consists of a septic tank of 56,500 gallons capacity, built entirely in concrete, and of two sand filters each 55 feet by 150 feet. A feature of the tank is a dosing chamber of about 11,000 gallons capacity. The cost of the plant will be $5,780.

ANALYSES OF IOWA SEWAGE AND SEWAGE DISPOSAL EFFLUENTS.

Parts per Million.

PLACE	Solids on Evaporation.	Ammonia.		Nitrates.	Oxygen consumed 4 hrs.	Bacteria per c c	Per cent. of Purification			
		Al.	Free				Al. Am.	Free Am.	Ox. Con.	Bacteria
IOWA STATE COLLEGE.										
Jan. 8—Mar. 28, 1901.										
Av. of 10 analyses.										
Raw sewage	1913	29.5	17.0	0	76.0	1149000	......	......	......	....
Tank effluent	1208	12.1	12.3	0	25.6	401000	59.0	27.6	66.3	65.2
Filter effluent	1221	1.7	2.6	7	3.1	10500	94.2	84.7	96.0	99.2
Apr. 4—June 13, 1901.										
Av. of 11 analyses.										
Raw sewage	1897	16.8	21.6	0	46.1	735000	......	......	......	...
Tank effluent	1346	14.8	19.9	0	19.7	474000	11.9	7.9	57.3	35.5
Filter effluent	1357	1.1	3.2	13	2.6	10700	93.4	85.2	94.4	98.5
June 20—Aug. 15, 1902.										
Av. of 9 analyses.										
Raw sewage	2309	49.5	21.4	0	50.0	769000	......	......	......	....
Tank effluent	1388	14.1	13.7	0	28.3	689000	71.5	36.0	43.4	10.4
Filter effluent	1414	1.5	0.7	14	2.7	14200	97.0	96.7	94.6	98.2
Aug. 22—Oct. 2, 1902.										
Av. of 7 analyses.										
Raw sewage	1694	29.7	36.7	0	49.1	3637000	......	......	......	...
Tank effluent	1323	28.0	31.4	0	13.3	2637000	5.7	14.4	72.9	27.5
Filter effluent	1490	0.6	0.5	15	2.1	6300	98.0	98.6	95.7	99.8
MARION, IOWA.										
Jan. 18, 1902.										
Raw sewage	632	18.0	16.0	0	16.2	....	......	......	......	....
Tank effluent	614	6.0	5.5	0	14.8	....	66.7	65.6	8.6	....
Pond effluent	550	2.5	11.0	0	12.2	......	86.1	31.2	24.7	....
SPIRIT LAKE, IOWA.										
About Oct. 21, 1903.										
Raw sewage	7120	10.0	72.5	0	121.3	....	......	......	......	....
Tank effluent	1582	21.0	53.5	0	123.8	....	-11.0	26.2	-2.1	....
Filter effluent	932	19.5	27.0	3.6	2.5	....	-95.0	62.7	98.0	....
Sept. 9, 1903.										
Raw sewage	12400	51.5	100.0	0	134.6	....	......	......	......	....
Tank effluent	12668	50.5	140.5	0	138.0	....	1.9	40.5	-2.5	....
Filter effluent	1970	2.5	40.5	0	5.2	....	95.1	59.5	96.1	....
GRINNELL, IOWA.										
Sept. 4, 1903.										
Raw sewage	1230	13.4	10.0	0	8.3	....	......	......	......	....
Tank effluent	1176	3.4	10.4	0	4.0	....	74.6	-4.0	51.8	....
INSANE ASYLUM, Mt. Pleasant, Iowa.										
Sept. 2, 1903.										
Raw sewage	2996	6.0	12.0	0	....	....	......	......	......	....
Tank effluent	2340	6.4	9.0	0	27.0	....	-6.6	21.7	-58.8	....
Filter effluent	2690	4.8	10.2	0	4.8	....	20.0	15.0	71.8	....
Oct. 22, 1903.										
Raw sewage	3212	12.5	30.0	0	46.9	9500000	......	......	......	....
Tank effluent	2266	17.5	40.0	0	151.7	2290000	-40.0	-33.3	-223.5	75.0
Filter effluent	2198	3.0	35.0	0	25.1	1332000	76.0	-16.7	46.5	86.0
SOLDIERS' ORPHANS' HOME, Davenport, Iowa.										
About Sept. 2, 1903.										
Raw sewage	740	6.0	21.0	0	30.2	....	......	......	......	....
Tank effluent	590	8.0	22.2	0	34.4	....	-33.3	-5.7	-13.0	....
Filter effluent	560	3.4	13.0	0	8.0	....	43.3	33.3	73.5	....
Oct. 24, 1903.										
Raw sewage	1656	17.5	26.0	0	91.3	3818000	......	......	......	....
Tank effluent	594	7.5	33.0	0	34.8	934000	57.1	-27.0	61.0	75.5
Filter effluent	608	20.0	16.0	0	34.6	463000	14.3	-38.5	62.1	87.5
GIRLS' INDUSTRIAL SCHOOL, Mitchellville, Iowa.										
About Sept. 12, 1903.										
Raw sewage	3370	22.0	162.0	0	145.4	....	......	......	......	....
Tank effluent	2536	4.0	50.0	0	153.0	....	81.8	69.1	-5.2	....
Filter effluent	3240	2.5	50.5	0	86.8	....	88.6	68.8	40.3	....
Nov. 27-28, 1903.										
Raw sewage	....	......	....	......	....	1018000	......	......	......	....
Tank effluent	....	......	....	......	....	551000	......	......	......	45.8
Filter effluent	....	......	....	......	....	297000	......	......	......	70.8

Caution must be given in connection with this table not to place too much reliance upon the results of single sewage analyses, because sewage fluctuates so widely in quality from minute to minute and day to day. For example a sample of raw sewage taken by the author at Mt. Pleasant in 1901 gave results indicating much greater strength than the first analysis in the table, while on the other hand the author believes the results of the single Mitchellville analysis given to be abnormally high. In connection with the Spirit Lake analyses it should be noted, in addition, that the polluting material is mainly casein, and hence the strength of the sewage is not well indicated by the ammonia. Here the solids on evaporation and the oxygen consumed give a better idea.

So far, the author has aimed to give simply the facts relating to sewage disposal in Iowa but he will now venture to express his more purely personal opinions on some of the debatable points of sewage disposal, opinions formed as the result of five years' experience with Iowa sewage disposal plants and investigations. These opinions are "subject to change without notice," as further developments may decide.

First, the fact should be emphasized that any sewage disposal plant requires intelligent and diligent care. It will not run itself, no matter what the design, or the claims of the designer. This requires impressing beforehand on the average town, and the engineer who designs a plant should count on keeping close track of it for years after it is built. The plant should be placed by the city in charge of an intelligent and faithful man, who should visit it frequently, attend to anything requiring attention, and report at once to the engineer any change of conditions or trouble for which he does not know the remedy.

The author does not mean that a large amount of labor will be needed in the operation. The septic tank will require occasional cleaning out, the interval depending upon the strength and character of the sewage. With weak sewage two or three years may pass between cleanings, and with ordinary sewage perhaps a year would be about right. Under other conditions, such as those at Spirit Lake, where the sewage is very heavily laden with a kind of solid matter which will not decompose in the tank, the tank should be regarded more as a settling basin, and emptied every few months.

The author would make a septic tank a feature of the plant. Not only does it retain and partially liquify the solid matter, and partially purify the sewage, but also it aids purification in a way which cannot be shown by analysis, by partially breaking up the organic compounds and leaving them in much better shape to be acted upon by the filters. This is shown in the process of making ammonia determinations in chemical analysis of sewage, by the much greater ease of distilling off the ammonia from a tank sewage than from a raw sewage.

The care of sand filters required is to loosen up the surface at intervals depending upon the freedom of the applied sewage from suspended material. At the college plant the intervals between loosenings are one to two months, while at Spirit Lake the beds should probably be loosened every week, though the tank is not properly cared for and hence the beds require more attention than they otherwise would. If much sediment comes from the tank it will be retained on the surface of sand filters and a few wheelbarrow loads are occasionally removed at the college plant. The best tool for loosening up the surface which the author has seen is an ordinary four-tined fork, with the tines bent by a blacksmith at right angles near their upper ends. This is very much superior to a rake or a hoe, since the sand can be readily loosened to a much greater depth, and the tines are far enough apart to permit the pebbles to pass between.

Contact filters also require loosening but not at such frequent intervals. At Mitchellville they have been dug up once in six months.

It is perfectly feasible to operate sand filters under Iowa winter conditions without covering where ordinary sewage is being treated. At the college plant the beds are furrowed just before freezing weather, and in very severe weather a roof of ice forms, supported on the ridges, under which the sewage flows. The application of sewage in considerable doses by automatic siphons is of importance in thawing out the frozen sand. The only particular trouble in winter is to keep the beds loosened, and they should be kept in good shape all the while so as to be ready for a very severe cold snap. The attendant may have to put on rubber boots sometimes, to be able to loosen the beds while the sewage is on and they are thawed, as after each dose disappears the sand freezes on the surface. With the very difficult sewage at Spirit Lake it is proposed to temporarily cover the beds with loose boards on wooden horses in severe winter weather. The contact filters at the three Iowa plants were operated last winter without any special difficulty, and contact beds will probably require less close attention in winter than sand filters.

As between sand filters and contact beds for the treatment of tank effluents the author would not lay down an absolute rule, but would decide each case by itself. Where the cost is equal, however, or nearly equal, he would strongly prefer sand filters. In Iowa by far the best results have been obtained with such a plant, and this confirms the comparative tests made by the Massachusetts State Board of Health. Especially as regards bacterial purification the sand filters give the best results. The author believes that, while giving due attention to cost and local requirements as to purity, the engineer should strive to secure the very best effluent possible, and that the better effluent can often be secured without additional cost. Other points in favor of sand filters are that they have been demonstrated to be durable, while it is not yet proven that the material of contact beds may not require periodical renewal or washing. The sand filters retain fine material on the surface whence it can readily be removed, while in contact beds it is difficult to prevent its being washed into the body of the filters. Sand filters do not require so much elaborate operating gear as contact beds. The material for sand filters is widely distributed in Iowa, while the material for contact beds is difficult to secure. The author believes that some American engineers have followed too closely developments in English practice without giving sufficient attention to differences in American conditions. The author would consider maximum rates of 200,000 to 250,000 gallons per acre per day not unsafe for properly designed plants treating ordinary sewage on sand filters, and using a septic tank for first treatment. The recent use of the septic tank and automatic operating gear have entirely changed conditions from the old days of intermittent filtration of crude sewage in Massachusetts. The possible rates for sand filters have been greatly increased, while on the other hand the high rates at first proposed for contact beds have had to be lowered.

While usually preferring sand filters, the author would not hesitate to use contact beds where the cost is materially less and funds for sand filters are not available, and where a less degree of purification is sufficient to meet the local conditions. Such beds have the advantage of requiring less labor, perhaps, in ordinary operation (not including renewals) especially in winter. The author would invariably employ double contact unless forced to single by lack of funds, and would be conservative as to the rates of filtration. He would not like to exceed 600,000 gallons per acre per day for beds three feet deep, which is about the rate at Davenport and Mt. Pleasant, allowing for greater depth, and would add area sufficient to keep one bed in four resting. The author would be glad to learn of contact beds operated continuously under actual working conditions in this country at actual higher rates than the above, and is open to conviction on this point. The author would not hesitate to build contact beds in earth without masonry, where suitable soil for water-tight embankments can be secured, and where there is no danger to adjacent wells from a little seepage.

The question of operating gear is of great importance with modern disposal plants, for sand filters no less than contact beds. To secure uniform application of sewage to the beds, and in winter operation, the sewage should be applied suddenly to the filter in intermittent doses of considerable size. The gear employed should be simple in design, and not liable to get out of order. Reliable gear can now be purchased on the market.

DISCUSSION.

Mr. Parkhurst—I would like to ask how long this plant at the State College has been in operation?

Prof. Marston—Five years.

Mr. Parkhurst—I think some information as to the details of operating these filter beds, contact filter beds, etc., would probably be of interest to the Society. How often are the cinders or material of the filter beds changed, if they are changed at all?

Prof. Marston—In giving the oral explanation, I omitted, I find, some things that are stated in the paper. The material in the sand filter beds is practically permanent; there have been but a few loads removed from the college filters in the five years of operation. It is a little too early to speak about how long the cinder filter beds will last as they have been in operation under Iowa conditions only since last December. The sand filters require to be loosened about once in two months.

Mr. Finley—How often do you clean out the septic tank?

Prof. Marston—At Marion the septic tanks were not cleaned for some two-and-one-half years. Our experience has not covered a period long enough to say with certainty how often they should be cleaned out. However, I should say they ought to be cleaned out once a year, with ordinary sewage. With sewage not of the ordinary kind the tanks might need to be cleaned out oftener.

Mr. Randolph—How thick do you find the deposit in the septic tank?

Prof. Marston—The tank at Grinnell was tested in July, and we tried then to ascertain what the deposit was in the tank; we did not find any at the middle and only a few inches at the end where the sewage entered. No scum had formed in the middle, but there was some at the end where the sewage entered. As stated in the paper the tank at Spirit Lake had become choked in two years with material floating on the surface, this material being mostly the casein extracted from the butter, in the butter refining factory which contributed most of the sewage there.

Mr. Poetsch—Is there much odor?

Prof. Marston—There is less odor about the college plant than there is around the pig pens which are adjacent. At Spirit Lake, with this very strong sewage of which I speak there is more odor, even 300 or 400 feet away from the plant, if the wind was blowing in that direction. In some cases I doubt if a person would know what was in the tank in simply walking over the beds. The odor depends on the character of the sewage.

Mr. Finley—What disposition is made of the refuse from the septic tank?

Prof. Marston—At the college plant we let it dry out and then load it on to wagons and haul it away, to be used as a fertilizer on the farm. Where tanks are designed as modern tanks are, it will be sufficient to provide a level area of soil, which can be plowed or otherwise loosened just before emptying the tank, and the sludge can be dug into this, or it can be allowed to dry and then hauled away.

Mr. Shnable—Is the septic tank built air tight?

Prof. Marston—Not necessarily. In the winter a tank which is open will be apt to freeze over on the surface, and there perhaps might be less difficulties with a covered tank than without, so we usually provide covers.

Mr. Poetsch—How long a time was the sewage at rest in the tank?

Prof. Marston—The tank at the college discharges perhaps on an average of twice a day.

Mr. Randolph—I would like to ask whether you consider the cinders or the coke breeze the more durable material?

Prof. Marston—I would say that coke breeze would be the more durable material, but it is also more expensive. In Iowa when we want a more durable material than the cinder filter, we could use fine crushed stone, or fine screened pebbles.

Mr. Parkhurst—In speaking of the sand filter I believe you said it was necessary to break or loosen up the material; would it not eventually be necessary to replace a portion of that sand with other sand?

Prof. Marston—I think not, except as some sediment from the tank might be carried out on the surface, in which case we might have to rake that up and remove a small amount of sand with it.

Mr. Parkhurst—What led me to ask that question was what you said in regard to forcing tines into it to break it up. Would not the use of crushed limestone at the bottom of the bed do just as well as coarse gravel?

Prof. Marston—Yes.

Mr. A. J. Cox—Is not 800,000 gallons per acre a pretty high rate for contact beds?

Prof. Marston—I, myself, would not use greater than 600,000 gallons per day, per acre, and think 400,000 to 500,000 would be preferable.

Mr. A. J. Cox—In regard to the rate at which contact beds can be operated successfully, much of course depends upon the standard required for the effluent. With the standard called for by the Fort Des Moines specifications, not over 550,000 gallons per acre per day should be exceeded for contact beds three and one-half to four feet deep, and more than one contact would be necessary to produce the required purification. I found that English practice varies widely. At Finchley the figures given me were 240,000 gallons (U. S.) per acre per day and at Sutton in Surrey, the "Mecca of the Sanitary Engineer" the beds were being worked at the rate of 360,000 gallons. These are conservative figures but the effluent in each case was said to be satisfactory to the Thames Conservancy Board. The filtrates were not brilliant. The Manchester experiments show that with one and one-half contacts, i. e. the secondary beds having one-half the area of the primary, the depth being three feet and four inches, worked at the rate of 480,000 gallons per acre per day gave results well within the standard of the Mersey and Irwell Joint Committee, which standard is a little more liberal than the standard called for at Des Moines. The City of Manchester is at present carrying out plans whereby the sewage of the city will be treated at a rate of about 600,000 gallons. The rate at Aldershot is 522,000, and at West Bromwich 640,000 gallons.

The rate at Hampton with triple contact beds is about 300,000 gallons. At Leeds a rate of 340,000 gallons was recommended, this to give ample reserve beds. At some places contact beds have been worked at rates of 800,000 to over 1,000,000, but I do not think that the results are satisfactory in the long run. The three plants spoken of in the paper will work at the high rates given, and they have not been successful thus far. The sewage in this country is generally much weaker than that in England, but I think the tendency is too make too liberal allowance for that fact and not have enough beds in reserve, if a high degree of purification is required.

Mr. Shnable—I would like to ask Prof. Marston what the effluent contains.

Prof. Marston—I have in my paper a table showing the results of chemical analyses. It is quite difficult to show in detail. In the effluent like the sample there will usually be from ½ to 2 parts of albuminoid ammonia. The diagram which was shown on the screen will show the exact figures for one year's operation of the plant. My recollection is that the diagram will show 3 or 4 parts of oxygen consumed in 4 hours. We also determine the nitrates. In some of this effluent we will find from 5 to 6 parts up to 30 of nitrates.

Mr. Cox—In the Marshalltown plant would not the sewage from the glucose works affect bacterial action, for would there not be considerable free acid in this sewage?

Prof. Marston—Yes, but not so large a per cent as is commonly supposed.

Mr. Cox—I was told by a London firm that they could not be certain of the results at Marshalltown.

Mr. Burdick—In regard to this plant which has been in operation for five years, I would like to ask whether there has been any analysis to determine the amount of purification secured by the tank?

Prof. Marston—Yes, we had a diagram thrown on the screen a few moments ago showing this.

Mr. Burdick—I did not notice that it gave the per cent obtained by the septic tank.

Prof. Marston—A table of chemical analyses in the paper shows the per cents of purification in the cases of the different tanks in Iowa.

Mr. Cox—I think you would not describe the Ames tank as a true septic tank. The tank itself is flushed out, thereby distributing septic action.

Prof. Marston—It is a little hard to define exactly what is meant by the septic tank.

Mr. Cox—Ordinarily a septic tank is not discharged in that way, is it?

Prof. Marston—It is a septic tank in this, that the bacterial (or septic) action occurs along the same lines as in any tank, although it may be modified by the fact that the water level in a considerable portion of the tank fluctuates.

Prof. Arthur N. Talbot, M. W. S. E. (by letter)—Prof. Marston's paper contains a valuable record of the development of sewage disposal in Iowa, and contains many suggestions for the design of sewage purification plants for our prairie cities. Iowa is representative of much of the Mississippi Valley in having many thriving small towns in inland locations, where sewage purification or partial purification is becoming a matter of present consequence.

The reference to the need of continued intelligent care of such plants is timely. Unfortunately, sewers and sewage disposal plants are expected to be self-operating. The need of supervision of water-works plants is apparent, and the financial returns make it easy to keep up interest and attention, but for the smaller towns a sewage disposal plant is very liable to be neglected. While it should be made as nearly self-operative as possible, the city authorities should recognize that good results require that careful supervision of the plant be maintained.

The discussion of the applicability of filtration beds and contact beds is interesting. The writer is of the opinion that the contact bed has not entirely come up to the predictions made for it, partly because the materials used in its construction are too often not of a permanent nature, and partly because the process of filling and emptying interferes with the biolytic agencies employed. Where proper distribution over the beds is obtainable, some form of rapid or intermittent filtration may be preferable. The difficulty in filtration is to get this distribution of the sewage over the bed, and not infrequently such beds fail of their purpose by reason of the sewage running quickly through the bed or being applied to a small portion of the bed. Where the surface of the bed is not very porous, and the sewage may be discharged on it intermittently in large quantities from a reservoir, as at the Iowa State College plant, the distribution will be very good. Continuous filters, with the distribution by sprinkling or other similar process, as used in several English plants, offer many advantages in continued aeration of the beds, and will give favorable conditions for purification, but this method of distribution cannot ordinarily be employed. Methods which give conditions approaching it are frequently applicable, as by discharging into channels which allow the sewage to percolate slowly outward, and the results have been satisfactory. Will not the author describe more in detail some of the methods of distribution of the sewage over the beds used in the plants described?

The increasing use of septic tanks by small towns seems quite marked. In this connection it would be of value to have the author state the results of his experience in reference to the necessary size of septic tanks for the treatment of ordinary domestic sewage. If data for the size of tanks to treat creamery refuse are available, such information will be of much value. Where considerable dilution of creamery wastes is possible, will not the difficulties of treatment and purification be greatly lessened?

Mr. W. S. Shields, M. W. S. E. (by letter)—The data and facts as given by Professor Marston, is of special value to all who are interested in the work and progress of sewage purification. His experience in Iowa is not unlike that of other engineers in adjoining states and results noted may be judiciously applied to like conditions elsewhere in the same latitude.

It would be interesting to those who have visited the Marion plant and there studied the governing conditions, to see analysis of the effluent first, as it leaves the tank before tumbling down the incline into the pond; second, as it leaves the pond, and third, as it enters the river. There is undoubtedly a marked degree of purification or change takes place between the tank and the river and this change is not unlike that secured by filtration. The aeration before entering the pond and its passage through the pond brings about the changes from the anærobic to the ærobic conditions, while the passage of the water through the ditch which, as I recollect, is some 600 feet in length with considerable fall, prepares it for the rapid nitrification which takes place as soon as it mingles with the water in the river.

At the time of my visit to this plant, which was in the latter part of May, the water in the pond was quite dark, but was giving off very little odor and the effluent showed a marked improvement as it entered the river; it was still dark in color but this disappeared almost entirely within a rod of its entrance and the color of the river water showed a marked improvement below the point where the effluent discharged into it.

The Fort Des Moines plant makes an interesting comparison with the one at the Mt. Pleasant Hospital. The requirements in each case being practically the same. One engineer uses the septic tank followed by double contact beds, finishes by sand filtration at the expense of $20,670; while the other guarantees to accomplish practically the same results by the use of the septic tank and single contact beds at an expense of $7,250, a case of two extremes. The one with the shot gun process and a profitable contract, should have no trouble whatever to exceed the guarantee of his contract; while the other with a losing contract, adopts a process which never can fulfill his guarantee under the peculiar conditions there existing.

I cannot agree with Mr. Marston in his statement that the contact bed system requires less attention than filter beds. The contact beds which have been constructed and are in operation in the western states, are not proving as successful as the filter beds. Whether this is from lack of skilled supervision, improper designs or of merit in the system itself, can hardly be determined until they have been operated a few years longer. I am personally inclined to believe however, that the contact bed is not destined to be a permanent feature in sewage purification and that the next five years will see it abandoned entirely and filters in some form or other substituted therefor.

The septic tank undoubtedly, will remain a permanent fixture in sewage purification, although in installations where large quantities of sewage is to be handled, it is not improbable that sedimentation, assisted perhaps by some form of coagulent, will be used successfully in the preparation of sewage for filtration.

The percolating open filter operated either intermittently or continuously and aerated naturally or mechanically, is destined to receive more attention than has been given it heretofore. It is adapted to all conditions where double contact beds are possible and besides being cheaper to construct, it promises to be less expensive to maintain and operate.

It is to be hoped that this paper of Mr. Marston's will be followed later by some results obtained from the plants which he describes, but which have not yet been put into operation.

CLOSURE.

Mr. Marston—Mr. Cox gives valuable data regarding the rates of filtration used in the case of English contact beds, and his statement that "the filtrates are not brilliant" is corroborative of the author's opinion, confirmed also by observation of the Iowa plants, that sand filters give much the better effluents.

The author is pleased that Professor Talbot and Mr. Shields have given their conclusions regarding the phases of sewage disposal, especially important at the present time. The author is in substantial accord with the opinions expressed by them. In adopting the use of continuous filters for actual sewage disposal plants the author anticipates, however, much trouble with the distributing devices in all cases where highly skilled supervision cannot be constantly exercised. Any failure of the distributing device to work properly must be fatal to satisfactory results, and, as complicated mechanical devices are required, much danger of unsafe effluents from such plants, especially for small cities is to be feared. It would seem that so far intermittent sand filtration furnishes the best and safest means for purifying the tank effluents. This is well illustrated at the present time by the plants at Lake Forest and Glencoe, Ill., just north of Chicago. At the former place sand filtration of the septic tank effluent is giving excellent results, while at Glencoe the operation of the double contact beds has been for some time abandoned.

In answer to Mr. Shields' suggestion that analyses of the pond effluent at Marion would be of interest the author would call attention to the fact such analyses are given in the table of analyses of Iowa sewage and sewage disposal effluents given in the paper.

The tank effluent was taken at the point where the sewage enters the pond, and the pond effluent at the point of exit. The analyses show that there was some further purification, but not a very large amount, effected by the flow through the pond.

Replying to Professor Talbot's request for information regarding the means used in the several plants for effecting uniform distribution of sewage over the filters, the author would say that at the college plant the sewage is carried in two pipes, one on each long side of each filter, with six openings on each side, and a wooden gate to control the flow from each opening. In later plants the author lays a line of sewer pipe with cemented joints on the surface of each bed along its center line, with crosses every ten feet, and by trial, from observations taken while the corresponding siphon is discharging, partially blocks the openings with cement to secure uniform distribution. At Spirit Lake this works with entire satisfaction. The pipe should be of large size. Those at the college are too small. With contact beds the means used for distribution is not very important, since the entire bed is filled with sewage each time anyhow.

Replying to Professor Talbot's questions regarding the size of septic tanks, the author would make them for ordinary sewage of capacity equal to 12 to 24 hours' flow of sewage, depending upon the local conditions.

Regarding creamery sewage the author would say that ordinary creamery sewage is not nearly so difficult to treat as the Spirit Lake sewage, which is from a butter renovating factory. The sewage from this contains a much higher amount of solids, and especially of casein, which will not decompose in the septic tank. At the Iowa State College we have had in operation three experimental tanks treating creamery sewage for about eight months, with satisfactory results. These tanks are of capacities respectively equal to 16, 24 and 32 hours' flow, and the following analyses may be of interest:

IOWA STATE COLLEGE CREAMERY SEWAGE SEPTIC TANK ANALYSES.

Parts per Million.

Capacity of Tank.	Date 1903.	Solids on Evaporation.	Al. Am.	Free Am.	Nitrites.	Nitrates.	Oxygen consumed, 4 hours.
16 hours flow...	May 26.	2768	17.0	39.5	0.0	0.0	53.6
	Oct. 2.	1902	4.0	11.0	0.0	0.0	34.2
	Oct. 9.	1904	2.5	5.5	0.0	0.0	34.2
24 hours flow...	May 26.	2692	39.5	49.5	0.0	0.0	86.0
	Oct. 2.	1896	6.5	33.5	0.0	0.0	36.4
	Oct. 9.	1866	0.5	4.5	0.0	0.0	43.1
32 hours flow...	May 26.	2828	21.0	57.5	0.0	0.0	74.7
	Oct. 2.	1786	5.0	20.0	0.0	0.0	34.1
	Oct. 9.	1836	4.0	4.5	0.0	0.0	38.8

So far, the smallest tank seems to give results fully equal to those of larger size.

As corroborating Professor Talbot's suggestion that creamery sewage may not be difficult to treat when mixed with ordinary sewage, I would say that at the college plant about 6,000 gallons of the 40,000 to 50,000 treated per day during the last five years is creamery sewage, and that no trouble whatever has been experienced with it.

ADDENDUM.

H. D. Wyllie (by letter)—Referring to Prof. Marston's paper on Sewage Disposal in Iowa, and the analyses of Iowa sewage and sewage disposal effluents submitted by him; I desire to make no comment thereon, further than to reiterate and emphasize what he says regarding the unreliability of single sewage analyses, and to add further that at the time his samples of sewage were taken the contact beds were badly clogged, due to inferior quality of filtering material and lack of attention. This has in a measure since been remedied, and although only a short time has elapsed since the filtering material was re-screened and replaced, analyses of samples taken at Davenport on November 13th and at Mt. Pleasant on November 19th and 26th, show considerable improvement.

ANALYSES OF SEWAGE MADE FOR THE CAMERON SEPTIC TANK CO.

Davenport, Iowa.

Date	Sample of	Alb. Amm.	Oxy. Cons.	Nitrogen as Nitrates and Nitrites.	Per Cent. Purification. Alb. Amm.	Per Cent. Purification. Oxy. Cons.
Nov. 13.	Sewage . . .	13.60	128.	. . . .	. . . .	. . . .
" 13.	Effluent. . .	4.50	88.	. . . .	66.9	31.3
" 13.	Filtrate . . .	1.05	17.6	1.00	92.3	86.3

Mt. Pleasant, Iowa.

Date	Sample of	Alb. Amm.	Oxy. Cons.	Nitrogen as Nitrates and Nitrites.	Per Cent. Purification. Alb. Amm.	Per Cent. Purification. Oxy. Cons.
Nov. 19.	Sewage . . .	15.80	196.	. . . .	. . . .	. . . .
" 19.	Effluent. . .	7.40	170.	. . . .	53.2	13.3
" 19.	Filtrate . . .	2.10	26.	0.10	86.7	86.7
" 26		2.05	26.	0.22	87.	86.7

The above analyses show parts per million.

D. B. Bisbee, Chemist.

CLXXXVII.

* THE HASKELL SELF-REGISTERING WATER GAUGE.

G. A. M. Liljencrantz, M. W. S. E.

Read October 21, 1903.

In presenting this paper before the Society, I need not touch upon the value of securing and preserving records of the fluctuations in lakes and rivers, as that fact is generally recognized. If however such records are incomplete, or still worse, unreliable, their value becomes doubtful, and in many cases even harmful, being misleading. On general principles, a wrong or unreliable information is often worse than no information at all.

It has been the custom in this district to observe the stage of the water-level three times a day, on ordinary board gauges, established in suitable places in the harbors or along the rivers subject to improvement by the Federal Government, thus to secure the daily and monthly means; but for obvious reasons, the results can hardly be considered as anything but uncertain as well as insufficient.

To secure a gauge Observer, at a reasonable compensation, who can be depended upon to read the gauge accurately and at the times required, and to make clear and correct reports of the readings is generally difficult, especially if the gauges are located so far distant from headquarters as to make frequent inspection impracticable.

The fluctuation in a river is ordinarily comparatively even and gradual, and a failure to read the gauge there, at the exact time specified,would not be of any material consequence. A considerable error in any isolated reading would also be at once detected.

In the Great Lakes the fluctuations are naturally very different. I base my statement on observations in Lake Michigan, assuming that the other lakes are similarly affected. The lake level may be said to be constantly fluctuating, generally slightly but occasionally to a considerable extent and during short spaces of time, and such an occurrence is very apt to be lost to the gauge-reader if observations are made only three times a day (usually at 6 A. M., at noon and 6 P. M.), and great changes may furthermore have taken place during the night, of which there would be no record.

To secure accurate data of this kind, automatic gauges have been invented, and one of these is made the subject of this paper, viz.: the one invented, in March, 1898, by Mr. E. E. Haskell, Principal Assistant Engineer in the office of the U. S. Lake Survey, in Detroit, Mich.

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* Known officially as "The U. S. Lake Survey Self-registering Water Gauge."

The first gauge of this type was placed at the St. Clair Flats Canal, in September, 1898. This having given the best of satisfaction, others have been made and put into service until there are at the present time 25 in use, including the one mentioned, viz.:

16 connected with the U. S. Lake Survey system;
1 at the mouth of Detroit River;
2 at Sault Ste. Marie, 1 above and one below the lock;
1 at Duluth, Minn.;
1 at Calumet Harbor, Ill.;
2 at Mobile, Alabama, and
2 at Toronto, Canada.

The purpose of this paper is not to furnish the necessary description by means of which a gauge of this kind may be constructed. It is manufactured by Mr. Louis J. Wohnlich of Detroit, under the immediate supervision of the inventor.

The aim of the writer is merely to give as clear an idea as possible of the main features of the gauge; its mode of operation; its value in securing reliable data, and finally to present some hints with regard to the manner of arranging its component parts in position for use, and to the care required when in operation.

It has therefore been considered undesirable to lengthen the paper with descriptions of minor details, not necessary to make the general system clear, however important these are in their various functions.

The subject will accordingly be presented under five separate heads, viz.:

A—General description;
B—Description of general parts;
C—How to put the gauge in operation;
D—How to attend to the gauge, and
E—General remarks.

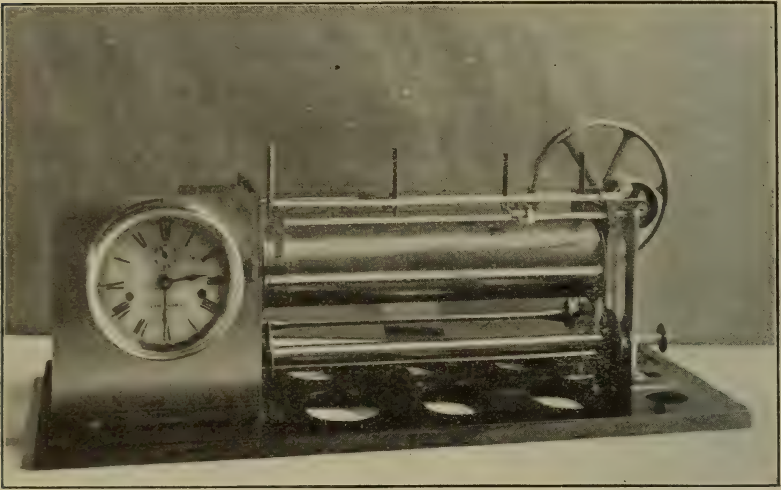
A—GENERAL DESCRIPTION.

The main features of the gauge consist in: A roll of paper so arranged that it will move at a fixed and uniform speed across a cylinder, above which four pencils are placed in such a manner that they will trace automatically the lines necessary to furnish a complete and accurate record of the state of the water-level at any desired moment, one of the pencils—the stage pencil—communicating with a float which follows the changes in the water-level.

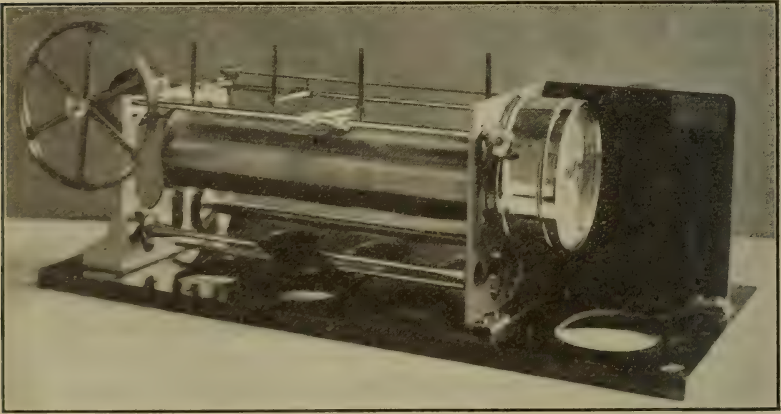
As the extreme range of fluctuation may be materially different in different localities, provision has been made whereby the fluctuation-curve may be produced in any of four different scales, viz.:

1 to 12, 1 to 8, 1 to 6, or 1 to 4, and the one of these which will keep the extreme limits within the boundaries of the paper is selected when the parts are assembled. For similar reasons, it is necessary that the float is given a chance to move freely to either possible extreme stage of the water-level.

The gauge is kept in a small gauge-house (Fig. 1) where it is protected as much as possible against the effects of violent wind-waves, and a bench mark is established close at hand so that read-



Recording Apparatus of Self Registering Water Gauge. Front view, showing Time Clock, etc.



Recording Apparatus of Self-Registering Water Gauge. Rear view. Float Wheel to the left, Driving Clock to the right.

ings by means of a staff-gauge may be made occasionally—in calm weather—to test the accuracy of the gauge records.

B—DESCRIPTION OF THE PRINCIPAL PARTS.

1. *The Frame.*—The main parts of the device are assembled in and about a frame consisting of a bed-plate of cast-iron, 14½ inches wide by 30⅝ inches long, stiffened by ribs longitudinally and transversely, and two end plates of cast brass, secured to the former by screws. These end plates are also fastened together by three phosphor-bronze or steel rods (a,a). The bed plate is firmly secured to a table of suitable dimensions, and this is in turn fastened to the floor of the gauge-house.

2. *The Paper Roll.*—The paper on which the record is to be produced comes from the manufacturer of the gauge in rolls ready for use. It is 16 inches in width and about 150 feet in length and is calculated to contain one month's record. As the paper is propelled at the rate of 2 inches per hour, or 124 feet in a month of 31 days, there is an excess sufficient for several day's run, and this is done to provide against a break in the record, in case the change of the roll should for some reason have to be postponed for a few days.

3. *The Driving Cylinder and Clock.*—The Driving cylinder (b) is made of brass, turned absolutely true so that its circumference is exactly 12 inches. It is 16⅛ inches in length, and is propelled by a clock (c) secured at one end to the outer side of one of the end-plates. At each end of the cylinder, $\frac{5}{32}$ of an inch from the flange, and at the quadrant points, are inserted steel needle points (at d d), about $\frac{1}{32}$ of an inch high, for the purpose of engaging the paper. The shaft on which the cylinder revolves is ⅜ of an inch in diameter, and has its center 6 inches above the base-plate. This shaft extends through the end-plate into the driving clock, and has a gear-wheel secured on its end, which engages with one of the driving wheels of the clock, so as to make one complete revolution in 6 hours, making its circumference—and conseqently also the paper which passes over it—move at the rate of 2 inches per hour.

The clock is an eight-day, engine-lever and 6-inch dial, made by The Seth Thomas Clock Co., of Thomaston, Conn.

4. *The Distributing Roller.*—The Distributing roller carries the roll of paper which passes thence across the Driving cylinder. It is placed back of the latter, with its axis exactly parallel to it, and with its revolving centers 4 inches lower, or 2 inches above the base plate. Its shaft is $\frac{5}{16}$ of an inch in diameter and 17$\frac{3}{32}$ inches long between shoulders, with turned bearings. Each end of this shaft is threaded for ¾ of an inch, and provided with a circular nut with milled edges and a conical washer, 1¾ inches long, ⅜ of an inch in diameter at the top and ¾ inch at the base, with a cyl-

indrical hole through the center, large enough to make a sliding fit on the shaft. By the aid of the milled nuts (e e) these cones are pressed into the paper roll, holding this firmly in its proper position. The shaft rests in bearings (f) in the end-plates. A brass spring is made to press against the under side of the paper roll to regulate its motion.

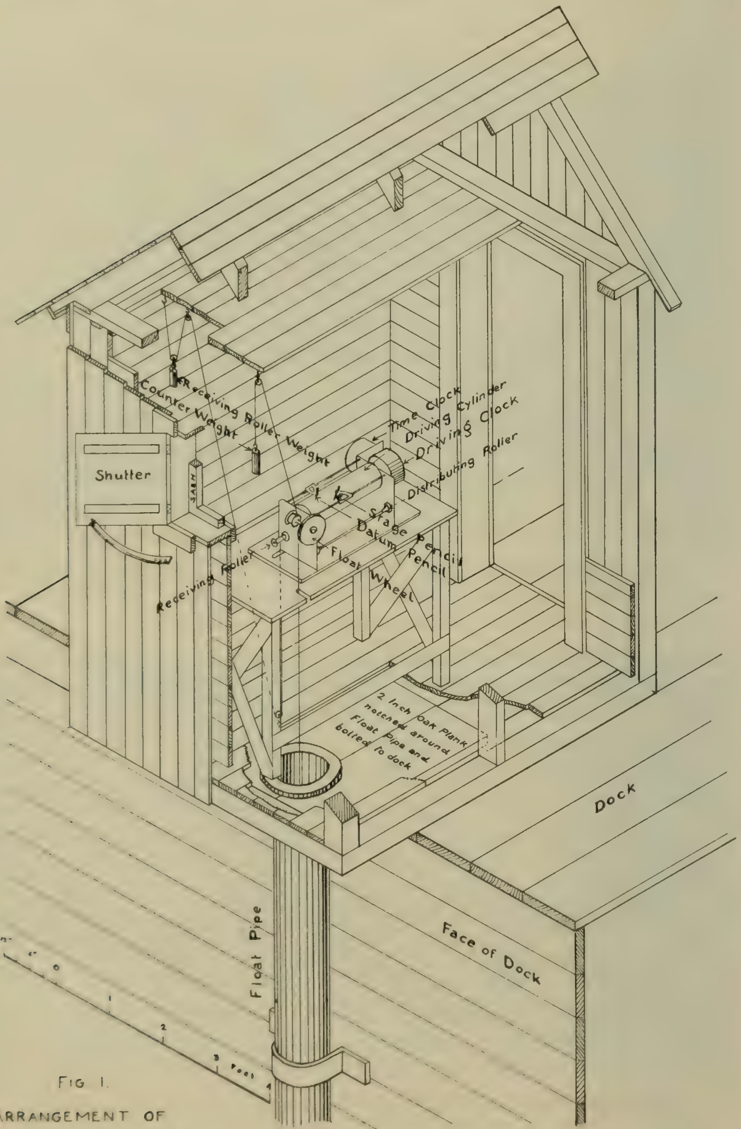


FIG 1.

ARRANGEMENT OF

GAGE, HOUSE AND PIPE

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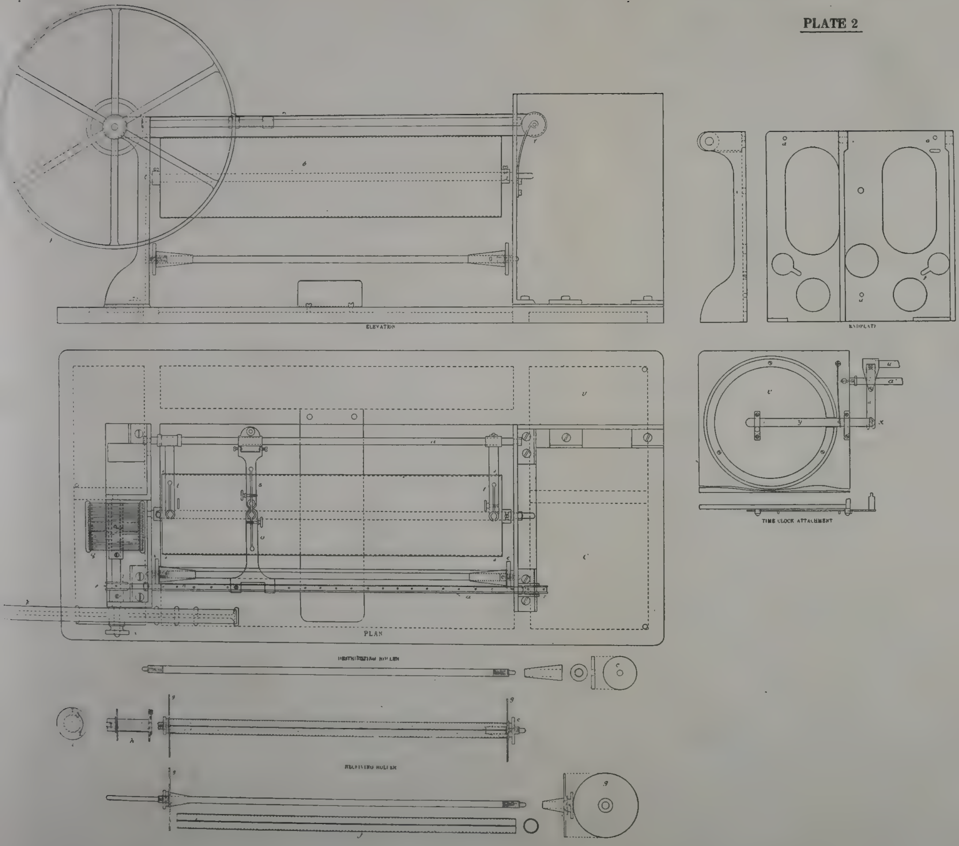
PLATE 2



5. *The Receiving Roller.*—The Receiving roller, on which the paper is collected after it leaves the Driving cylinder, is placed in front of this cylinder and in the same relative position to it as the distributing roller. Its shaft and other principal parts are also nearly identical with those of the latter. The main points of difference are as follows: Between the milled head and the conical washer at each end of the shaft is placed a flange (g), 3 inches in diameter, which serves to guide the advancing paper to its proper position on the roll. The head, nut, washer and flange are securely fastened together at one end of the shaft. At the other end, the shaft is threaded, like that for the Distributing roller, so that these parts can be removed when the roll of paper is to be taken off. At this end the bearing is extended to a length of 2½ inches, thus reaching some distance beyond the end-plate. Over the extension is fitted a spool or reel (h), fastened to it by a set-screw. Around the spool is wound a cord which, through its connection with weights and pulleys, causes the Receiving roller to take up the paper as it is fed by the Driving cylinder. By means of a ratchet (i), attached to the side of the spool, the cord may be wound up without taking it off or disturbing the roller. A brass tubing (j) is also provided for this roller. It is $16\frac{1}{16}$ inches long, with ⅝ inch internal diameter. Through one side of it, lengthwise, is cut a slit about $\frac{1}{32}$ of an inch wide. The tube is held firmly between the circular flanges, and fits tightly over the conical washers.

6. *The Float Wheel and Attachments* (Plate 2).—At the top of one of the end plates, outside of and parallel to it, is placed the horizontal shaft for the float wheel (k), which is placed at its outer end. The size of the float wheel depends upon the scale to which the fluctuation-curve is to be produced. The four different sizes provided have been alluded to hereinbefore. As these differ mainly in the size of their respective diameters, a description of one of them will answer for all. The outer face of the wheel is chased 20 threads to the inch and of such size that once around, measured with a No. 22 wire (standard gauge) laid in the bottom of the groove, shall give the exact length that will produce the proper ratio between it and the circumference of the small pulley (l) described below, on the same shaft. This ratio corresponds to the scale selected for the fluctuation curve.

The wheel is nicely fitted to its shaft and clamped in position by a circular milled nut (m). A small hole, just admitting the No. 22 wire, is drilled radially through the rim and at the bottom of the groove, for the purpose of securing the float-wire to the wheel.

Next on this shaft is the small pulley (l) alluded to just above. It is exactly 3 inches in circumference and moves, by means of a metal tape (n), the stage-pencil (o) that traces the fluctuation-curve. As has already been mentioned, the ratio of its circumference to that of the float-wheel determines the scale of the record. This pulley has 4 small studs (p), set radially in the center of its face at the quadrant points, and these studs engage in corresponding holes in the metal-tape to prevent slipping. The studs are $\frac{1}{16}$ of an inch in diameter, with hemispherical ends. The pulley is secured to the shaft by a set screw.

On the same shaft, and also secured to it by a set screw, is another pulley (q), the face of which is chased 10 threads to the inch. Over this is wound a cord which, passing through a pulley at the ceiling, is attached to a counter weight, and is designed to keep the proper tension in the float-wire. The tape-band is supported by a small spring-seated idler (r), placed outside of the opposite end-plate, which will keep it taut under all conditions of temperature. It is made of phosphor-bronze, 43 inches long and ¼ inch wide, with holes ¾ of an inch apart along its center, for purposes referred to above. The ends are fastened by screws to the carriage for the Stage-pencil.

7. *The Four Pencils and Holders.*—The Stage-pencil carriage is attached to, and propelled by, the tape-band as just stated. The frame, made of brass, consists at one end of a split arm to which the pencil is fastened with a clamp-screw. The opening for the pencil is threaded to hold it firmly. The other end of the frame, located below and attached to the tape-band, is forked and has holes through the two arms, well fitted so as to permit the frame to slide along the connecting rod between the end-plates, this rod serving as a guide.

The holder for the Datum-line pencil (s) has the end with the pencil-attachment similar to the Stage-pencil carriage. The other end is provided with a clamp-screw by means of which the holder is secured to the connecting rod in front of the instrument. The two parts are pivoted together, so that the part holding the pencil can be lifted up from the paper.

The two Time-pencil Holders (t,t) are exactly alike, with identical arrangement for holding the pencils as for those described above. They are firmly attached to a brass-bar (u) and thus held at a fixed distance apart. The position of this bar is just above the same connecting rod to which the Datum pencil is attached. To the pencil holder nearest to the Time clock (v) is secured a vertical arm (w), which is pivoted to the rod below and so arranged, that a motion given to the end of the lower end of this arm (at x) will be transmitted to the bar that carries the pencils, giving to these simultaneously a corresponding motion. The motion referred to is produced through the medium of its connection with another horizontal bar (y), which again connects with the works of the Time clock and will be further referred to in the description of that clock.

A small cylindrical weight is provided for each of the pencils to insure their pressure against the paper.

8. *The Time Clock.*—The Time clock is exactly like the Driving clock and has in addition a cam fastened to the back side of the wheel operating the hour hand and a suitable mechanism which—through the rod referred to in the previous paragraph—is connected with the time-pencils, in such a manner that on the exact hour they will be given a sharp push which is recorded in the shape of jogs in the lines made by the Time pencils at each side of the paper.

Lines drawn across the paper so as to connect the corresponding jogs and intersect the datum line and the stage curve, will facilitate the reading of the respective stages of the water level at each hour and, by interpolation, the stage at any desired moment.

The general feature of using two clocks is by the inventor credited to Mr. F. M. Little, of the Tidal Division of the U. S. Coast and Geodetic Survey, though modifications have been made in some respects from the application made by him.

9. *Miscellaneous Parts.*—The Counter Weights are made of brass, cylindrical in form, 5 inches long and 2 inches in diameter. They are hollow with removable covers and filled as may be required with No. 4 shot. The necessary pulleys are furnished with the weights.

The Float is made of best sheet-copper, the upper part being cylindrical in form, 8 inches in diameter and 2½ inches high; the lower part being cone-shaped and 2⅜ inches in height. It has a ballast of 1½ pounds of lead firmly soldered to the copper cone.

The Float-pipe (Fig. 1) is not furnished with the instrument. The one used in Calumet Harbor was obtained from J. B. Clow & Son of Chicago. It consists of an iron pipe with 9 inches internal diameter, a cast-iron cap screwed on to the bottom and a flange at the top. One foot from the bottom is a drilled hole, ⅜-inch in diameter for ingress and egress of the water. The height of the pipe is decided by the extreme range of fluctuation in the locality where it is to be used. The column of kerosene, used in the pipe as stated later on, should also be considered in this connection. The Calumet Harbor pipe is 20 feet long.

All brass work, with the exception of wearing surfaces, are lacquered for protection against the action of water.

C—HOW TO PUT THE GAUGE IN OPERATION.

The first thing to be done in putting up the gauge is to place in its proper position the iron pipe which is to hold the float. It must be firmly secured in an exactly vertical position and with its top at the floor of the gauge-house. To prevent the water in the pipe from freezing, pour in 15 gallons of kerosene. This will occupy a space 4½ feet high in the pipe.

Next, put that float-wheel, which corresponds to the scale selected for the stage-curve, on its shaft, but without clamping it; place the table, with the instrument secured to it, in such a manner that a plumb-line passing through the center of the float-pipe will be a tangent to the middle of the outer face of the float-wheel; then fasten the table to the floor. Set the Datum pencil at the place, approximately, where it would trace the plane of reference on the paper; put the float, with one end of the float-wire attached to it, into the pipe and fasten the other end to the hole in the rim of the float-wheel, after having made sure that the wire is long enough for the greatest possible fluctuations; turn the float-wheel (*not* the shaft) around so that the float-wire will be wound up in the groove made for it, until it is taut; move the Stage pencil to a position where it will indicate, approximately, the stage of the water-level as observed by the staff-gauge; then clamp the float-wheel to its shaft and attach the counter weight. The two pencils are then in *nearly* correct positions, relative to each other.

To place the paper in position, remove the nut and conical washer from one end of the Distributing roller; insert the steel-rod into the paper roll and replace the nut and washer, turning the former until the cones hold the paper firmly; then put the roller in its place in the frame. The holes in the endplates will admit the milled nut far enough for insertion of the roller into its bearings. Unroll enough of the paper to have it reach across the Driving cylinder and a couple of times around the Receiving roller; cut the paper so the end will form a blunt angle in the middle; make sure that the tension of the paper is equal at both ends of the Distributing roller before it is allowed to engage with the fine needle points on the Driving cylinder, as it is of material importance to prevent the paper from moving to one side, which it would certainly do if started unevenly. When the paper is correctly placed over the Driving cylinder, insert the blunt-angled end of it into the slit of the split tube and revolve this until the paper is drawn taunt, and equally so at each end of the roller; then attach the counter weight. This is done by letting the cord from the spool pass through a pulley attached to the floor, thence through another at the ceiling; thence, through a third pulley on which the weight is carried, to a hook in the ceiling. The weight for the float-wheel is attached to a pulley suspended on the cord which passes around the grooved wheel on the float-wheel shaft and has its other end fastened to the under side of the table.

The Time pencils are in their proper positions when the instrument is received from the manufacturer, and care should only be taken that the proper connection is made between the bar from the Time clock and the arm through which the motion is transmitted to the pencils.

The points of the Stage pencil and the Time pencils should always be in one straight line, for obvious reasons.

When the various parts are thus all in their proper positions, wind up both the clocks (two springs in each). Should either of the clocks fail to start, stick a fine wire through the regulating slot in the face and hit the balance wheel; a light side-movement of the wire will do the work.

As will be remembered, the Stage and Datum pencils were placed only in their *approximately* correct positions. They should now be accurately adjusted. This requires a calm day, when a correct and close reading of the staff-gauge can be secured. Such being the conditions, loosen the clamp that holds the Datum pencil to the rod and move this pencil until the distance between its point and that of the Stage pencil corresponds exactly to the reading of the staff-gauge ; then clamp the Datum pencil again firmly. This operation should, of course, be done as quickly as possible. Several tests of this kind should be made to secure the greatest possible accuracy, after which the Datum pencil should not be further disturbed. When everything is in working order, slip the small cylindrical weights over the pencils.

D—HOW TO ATTEND TO THE GAUGE.

A description of how to attend to the gauge is given in a circular of instructions sent to the gauge tenders from the U. S. Lake Survey Office in Detroit, and a copy of this, slightly modified, is as follows:

1. Visit the gauge at least every second day and carry out the following instructions:

2. Wind up the weight of the Receiving roller at each visit to the gauge.

3. Wind up both clocks once a week, say every Saturday or Sunday.

4. When pencils are set see that the point of the Stage pencil is on a straight line between the points of the two Time pencils, which may be tested by stretching a thread from the point of one Time pencil to the other and then screwing pencils up or down in the holders until all three are in line. Also see that the paper is running straight over the drum, and if not, shift the paper on the Supply roller until it feeds properly. Keep pencils well sharpened.

5. Read the staff or check-gauge with extreme care and immediately mark the position of the point of the Stage pencil, by

taking hold of the float-wheel and turning it slightly in the direction that will lift the float out of the water, letting it back carefully. Opposite this mark write the reading of the staff-gauge, the time as indicated by the Time clock, and true standard time, using the 24-hour notation, counting from midnight. Next write the date (month, day and year).

6. Should the Driving clock be found stopped, write this fact on the roll and then start it and make the record above indicated. Should the Time clock be found stopped, write this fact on the roll and also the time as indicated by its face when it stopped. Start the clock, set it to correct time and make the record above indicated.

7. When the Time clock gains or loses, it should be set correct whenever the error has become as much as 5 minutes, and this fact should be stated after the usual entry, thus: "Clock set correct." Do not attempt to turn the hands of this clock *backward*, past the hour without pulling the bar that moves the time pencils to the right to release the cam.

8. The paper should be changed preferably on the 1st or 2d of the month. The roll taken off should be carefully wrapped and sent to the office. An extra roll of paper should always be on hand.

9. Should the float-wire happen to break or get off the float-wheel, this fact should be written on the roll. If the old wire cannot be spliced, a new one should be put in and as soon as the gauge is again in working order, the staff-gauge should be read, and the usual record made on the roll.

10. Great care should be taken to have all the pencils make good plain marks. To this end it is advisable to keep a piece of fine sand-paper or emery-paper at the gauge-house, and at each visit draw it two or three times across the points.

To the above directions may be added:

11. When the record for the month is completed and the paper-roll is to be removed, take the counter weights off; remove the spool at the end of the Receiving roller, when this can be taken out of the frame and the paper-roll abstracted.

12. Do not forget to note and mark on the Stage-curve, the exact time when the *old* record was taken off as well as the time when the *new* record was started.

E—GENERAL REMARKS.

During the time the Calumet Harbor gauge has been in operation, there have been some days of exceptionally great and sudden fluctuations and it has been deemed of interest to exhibit the records for these days. The first diagram (on Plate 3) shows the record from 8:00 A. M. on June 30, to 8:00 A. M. on July 2d, 1903. This is

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PLATE 3.

HYDROGRAPH
showing Excessive Fluctuations in Lake Michigan
from 8 a.m. June 30
to 8 a.m. July 2, 1903,
as obtained from the selfregistering
WATER GAUGE
at
CALUMET HARBOR, ILL.

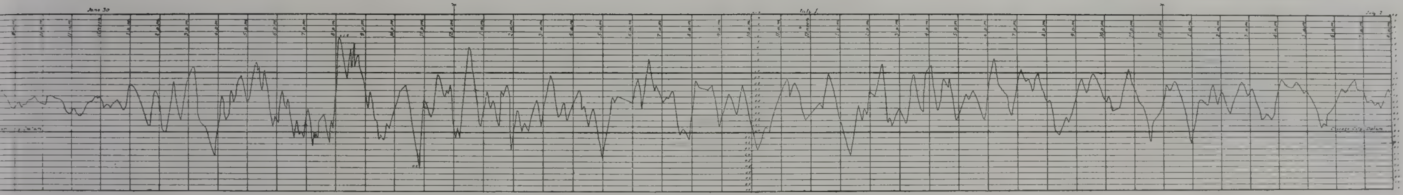
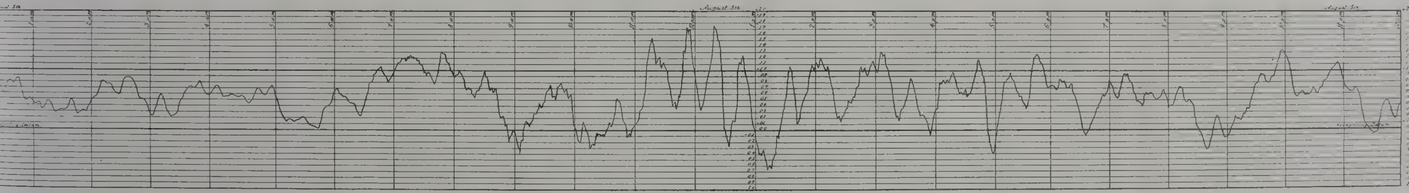


FIG 4. HYDOGRAPH FOR AUGUST 6, 1903.



a copy of a diagram forwarded with the Annual Report to the Chief of Engineers. The horizontal scale was reduced on this, to 1 inch to the hour, for the purpose of lessening the length of the drawing by half. The second diagram is for the 5th of August, and is taken from the original record.

To the automatically traced lines have been added the hour-lines and the lines showing the vertical scale in feet and tenths.

The lines traced by the Time pencils are omitted on the diagrams to lessen the width of the drawing. To indicate their character, however, one of them has been shown below the diagram for August 5th.

The U. S. Lake Survey Office computes the daily means from the 24 readings taken at the hour-lines on the record sheet. It occurred to me that, at times of great and rapid fluctuations, the result thus obtained might be far from accurate, and that absolutely correct means might be obtained by integrating—by means of a planimeter—the area bounded by the Stage-curve, the hour lines and the Datum line (or a line parallel to it) and divide by the distance between the hour-lines used. To satisfy myself on this point, I computed the means for the 48 hours represented by the first diagram, by 3 different methods; viz: From three daily readings (6 a. m., noon and 6 p. m.) from hourly readings and by integration. I anticipated a considerable difference in the results and was rather surprised to find them as follows:

Daily means on—	June 30.	July 1.
From 3 readings,	0.42	0.45
From 24 do,	0.47	0.45
By integration,	0.52	0.48

The extreme range of fluctuation during this period was:

On June 30, 2.2 feet; on July 1, 1.8 feet.

The range for the two days combined was the same as for June 30, the extremes having been reached on that day. The very slight difference obtained from the different methods—the greatest being only 0.1 foot—might have been incidental, i. e., that the isolated hourly readings may have happened to be nearly the same as the means for the day, and the extremes may have occured in the intervals. It is proposed to proceed in the same manner with the record for the whole of the month of August, on the result of which a more conclusive opinion may be based.*

The hole in the float pipe should, according to directions, be made 3/8 of an inch in diameter. The writer must confess to some doubt as to whether such a small hole would be absolutely sure to record the extreme fluctuations when occurring in such a short space of time as occasionally happens in Lake Michigan. Too large a hole, on the other hand, would record strong wind-waves in a manner that would make the stage curve blurred and indistinct, which is also unsatisfactory. To test the accuracy of the traced curve, it is now intended to place at the Calumet Harbor gauge, a device which is practically the same as the "Maximum and Minimum Gauge" devised by the writer a number of years ago and described in a paper before this Society.* This arrangement will include a device by which the substitute for the staff gauge may be read on the wall of the gauge house directly in front of the automatic gauge, furnishing an easy and convenient means of comparing, simultaneously, the readings of both. By observing the Maximum and Minimum pointers, comparisons may also be made with the range of fluctuation as indicated on the record sheet, for any desired period. If the two differ, it remains to ascertain which is correct. If they agree, it may be fair to assume that both are correct.

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*The means "for the month of August" have since been computed in the same manner, and the results were:

From daily readings, 0.568 ft.
From 24 daily readings, 0.581 ft.
From integration, 0.565 ft.

In attending to the gauge, when it was first put up, the writer experienced some slight difficulties with some details of the work, and having successfully contrived some very simple means for overcoming them, it may not be amiss to mention them for the benefit of others who may have similar experience.

When placing the paper in position in the instrument, the four pencils proved a hindrance, and I found it necessary either to let them drag on the paper or have a helper to hold them up, as the accurate position of the paper on the roll is a very important item, requiring careful attention.

As a remedy for this, two cords are suspended from the ceiling, their respective lower ends being attached to each end of a stick, the length of the cylinder; the position of the stick to be parallel to the same and about three inches above it. Four rubber bands attached to the stick, one above each pencil, furnish means of suspending them when the paper is to be inserted. As the Stage and Datum pencils must be in such a relative position to each other that the former can pass the latter when the water level changes from above to below the plane of reference, or vice-versa, a scale placed at the nearest pencil point (that of the Datum pencil) will be some distance from the other, and a close reading cannot very well be made. This drawback is easily overcome by letting the point of the Datum pencil rest on the zero line of the scale, which can then be moved up close to the point of the Stage pencil and facilitate a very close reading.

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*January 18, 1881, Vol. 6, Proceedings of Western Society of Engineers.

DISCUSSION.

Mr. Benezette Williams, M. W. S. E.—What is the cost of that gauge?

Mr. Liljencrantz—$140.

Mr. T. T. Johnston, M. W. S. E.—I would like to ask Mr. Liljencrantz what the highest level is of Lake Michigan, so far as he knows?

Mr. Liljencrantz—The official Milwaukee plane of reference is the high water of 1838, which is 3.06 feet above the mean lake level, and that is 1.80 feet above the Chicago City Datum, which will make the high water 4.86 feet above Chicago Datum, but I do not believe that the water-level has reached that height for many years back, except in the form of momentary waves.

Mr. Seddon, M. W. S. E.—Have you made any computations on the interval of oscillations in the lake? It is a pendulum movement, is it not?

Mr. Liljencrantz—No, I have not, but I think that gauges of the kind just described, if placed along the shores of the lake and adjusted accurately to one common standard of time and referred to one common plane of reference, would offer favorable opportunities for a study of this problem and prove of much interest.

Mr. Warder—Looking at that lower diagram, the vertical lines 2-inches apart represent equal intervals of time, I understand?

Mr. Liljencrantz—They represent one-hour intervals.

Mr. Warder—In some parts of the diagram it appears that the highest elevation of water is for but a brief time, and the maximum variation between the highest and lowest points is much less than an hour, and may have been less than ten minutes?

Mr. L. E. Cooley, M. W. S. E.—There was an automatic gauge on the Intake Crib in Mr. Chesbrough's day, and I made a study of the records in 1876 and 1877. So far as I know, that was the first time attention was called to that matter. The intervals were about 20 minutes. I applied Sir John Airy's formula for travel of earthquake waves to the depths on the published charts and found the time to opposite shore and return was 18 minutes. That corresponded sufficiently close. These phenomena have been specially investigated on Lake Geneva in Switzerland so the matter is not entirely new. The lochs of Scotland have similar phenomena and foreign observers have applied to them the name of Seiches.

In 1886 I had charge of the lake investigations for the Drainage and Water Supply Commission. We had an automatic gauge at that time. We had 20 minute fluctuations, reaching on one occasion 18 inches change of level. I attempted to test the matter of oscillation from shore to shore by establishing five gauges around Lake Michigan at different points—Menominee, Milwaukee, Ludington, Grand Haven and St. Joseph—having them read by standard time at five minute intervals. We did not select days in which the phenomena were characteristic, but so far as we could make out, there was a rise on the opposite shore corresponding to the depression on this shore, and vice versa. We discovered a result wholly unexpected. The gauge at Chicago went down something like 0.5 feet but it went down on all the other gauges on Lake Michigan—the whole five—and that led to speculation as to where that water went. We made some computation on the Straits of Mackinac and concluded that the water could get over into Lake Huron. The matter was not followed to a conclusion, but it seemed to be the opinion that the water could be transferred from one lake to the other.

Mr. Liljencrantz—I recollect that the Sanitary District had an automatic gauge established in Chicago Harbor, but I do not remember what make it was nor wherein it differed from this.

Mr. Cooley—It was a gauge made at Philadelphia. It worked very well and gave very satisfactory results.

Mr. Johnston—It may be a matter of a little interest to know that Mr. Chesbrough, in the course of his reports as city engineer, makes a statement that at one time the level of the lake got to be 9 feet above Chicago Datum.

Mr. B. Williams—There have been several tidal waves in the last fifteen or twenty years, and I know of at least one fluctuation of eight feet.

Mr. Randolph—How long did that continue?

Mr. Williams—A few minutes only, I shoul say.

Mr. Shnable—I can testify to a tidal wave which rose within three inches of the top of a cofferdam that we built across the South Lagoon in Jackson Park. The top of the cofferdam was +8 Chicago Datum. It lasted but a few minutes and recededas suddenly as it came.

Mr. Liljencrantz—The easterly breakwater has a superstructure that is about six feet above datum. If there had been a rise of eight feet, or two feet above the breakwater, this would have been entirely lost to sight. I have never had the fortune of witnessing such an occurrence.

Mr. Johnston—I would like to ask Mr. Liljencrantz if it is not a fact that a boat has at one time gone over the superstructure?

Mr. Liljencrantz—A boat tried on one occasion to pass over the exterior breakwater, but that was before the superstructure was put on.

Mr. Cooley—All the data that was extant in regard to lake levels, was compiled by the International Deep Waterways Commission in 1896, and published in its report. The high water of 1838 was established by Dr. Lapham at Milwaukee. It was 4 feet 9 inches above Chicago Datum. The low water of 1819 was 1 foot 8 inches below this datum. The extreme normal range for the century was 6 feet and 5 inches.

CLXXXVIII.

THE USE OF SUPERHEATED STEAM.

By Prof. Storm Bull, M. W. S. E.

Read Nov. 4th, 1903.

Anybody who has followed the development of the steam engine during the last few years, cannot help having noticed the increased use of superheated steam, especially in European practice. All new steam plants of any considerable size, and even many smaller ones, on the continent of Europe are now using superheated steam; and in the last couple of years a number of plants utilizing superheated steam have been built in this country. It cannot be doubted, however, that the United States has been behind Europe in this respect and that it is high time that we try our very best to at least equal our competitors in this branch of mechanical engineering. Because of the comparative newness of the subject it is very possible that a great many American engineers do not realize its importance and it is, to a certain extent at least, the purpose of this paper to try to convince the skeptical ones that it is necessary to use superheated steam in order to attain the highest commercial efficiency of the steam plant—not of the steam engine alone—but of both engine and boiler combined. To avoid misunderstanding it is perhaps necessary to state at this place that this does not apply alone to the ordinary reciprocating steam engine, but also to at least the same degree to the steam turbine.

Probably most of you know that the use of superheated steam is not new; on the contrary, it is probably not far from 75 years old. The old masters in steam engineering, without doubt, realized the fact that the principal loss of efficiency in the steam engine was due to the condensation of steam in the cylinders, and, as is well known, they tried a great many means to reduce it and with varying degrees of success. There is no question in the minds of all competent authorities that the best means of reducing the condensation is in the use of highly superheated steam, and this has been known for a great many years. It almost seems that the "grand old man" James Watt anticipated or at least had a presentiment of nearly all the improvements in the steam engine which were to be introduced into its design during the last century. However, it seems that he had no knowledge of superheated steam or of its advantages, which seems very natural, as he really was the first one who had an adequate and thorough knowledge of saturated steam. The first mention of the practical use of superheated steam, which I have been able to discover, is found in the "Life of Richard Trevethick" of the Binner-Downs Mine in Cornwall, England. In this book it is stated that a certain Captain McGregor in 1828, in order to compete with a record established by an engine of a neighboring mine, whose cylinders had been insulated with sawdust, built a jacket of brick around the cylinder and the steam pipe, with an air space between the brick work and the iron and that he built a fire in this open space, by which means he increased the duty of his engine from 41,000,000 to 63,000,000 foot-pounds per bushel (86 pounds) of coal. Trevethick himself tested the 70-inch cylinder engine with steam at 48 pounds pressure and which made 8 strokes per minute, and he found that by using 5 bushels of coal in 24 hours under the cylinder, he reduced the consumption of coal by the boiler from 108 to 67 bushels for the same work, showing a saving of more than 26 per cent. That such a saving must necessarily have aroused attention is evident; but it has been impossible for me to find any trace of it in the published records. In 1834 John Ericsson made some experiments with superheated steam, but no record of these experiments have been found. The next record that I have been able to find is that in 1845 Mr. Longridge made several experiments with superheated steam at low pressure, and in 1851, he was followed by Rafford in France who took out patents for a superheating plant.

From this time on, and lasting, perhaps, for 20 years, the interest in superheated steam was very active. Among the many engineers and scientists who contributed to the progress in this line should be mentioned especially Hirn, Isherwood and Faraday. The first named made a great many experiments in 1857, using steam of 55 pressure and temperatures ranging from 410 to 490 degrees Fahrenheit. The results of his accurate experiments showed an increase in the economy of the whole plant of from 20 to 27 per cent.

During the fifties and sixties, however, the principal use of superheated steam was found in the marine engine, and in the literature of the subject quite a number of tests of steamships with and without the use of superheated steam may be found. Penn showed an increase of economy of 20 per cent for the steamer Valletta with a steam pressure of 20 pounds. The Parson and Pilgrim's superheater was especially designed for marine practice. It consisted of a number of semi-circular pipes placed in the furnace, by which means it is stated that a saving of one-third in fuel was realized. The English Board of Trade, however, objected to the use of superheated steam on the ground that the high temperatures used were liable to break the steam up into its elements, thereby making it unnecessarily dangerous. Fortunately, Professor Faraday, who fully investigated the matter was able to convince the authorities that this objection was unfounded. The tests of marine engines made at about the same time, during the latter part of the fifties, show gains in economy of from 20 to 30 per cent, always depending upon the amount of superheat which was available.

Our own Isherwood was at first very skeptical as to the practical use of superheated steam. He at first declared against it on the ground of injury to the cylinder, difficuly of lubrication, extra weight and short life on board of ship. Later on, however, he recommends the use of superheated steam because of the gain in economy of 30 per cent shown by his experiments, but suggests that the limit of superheat be placed at 100 degrees Fahrenheit, on account of the difficulties of lubrication. In 1863–1864, he made extensive tests on the steamer, Eutaw, which had a single cylinder inclined engine with poppet valves and a Stevens' adjustable cut-off. The best results of these tests show a gain in steam economy of 18 per cent and 15 per cent in coal consumption.

During the years from 1850 to 1870 a great many superheaters were installed, especially on shipboard, notwithstanding the fact that engineers always found great difficulties with respect to the lubrication and that the material of the superheaters did not withstand the action of the heat for a very long time. That there was trouble with the lubrication should not surprise anyone when it is remembered that none of our present day mineral oils were known at the time, and that the only available lubricating materials were animal oils and fats. The steam pressure used up to that time did not exceed 50 pounds, at least not on ship-board, and for such a pressure the animal oils or tallow answered very well, even if the steam was superheated perhaps 100 degrees Fahrenheit. But the latter part of the sixties saw the introduction of the compound engine with its accompanying higher pressure, and this proved to be a very effective damper to the use of superheated steam,—and for two reasons. The first one was the very much greater economy of the compound engine as compared with the single expansion engine using steam of lower pressure, and because of this increased economy a saving of both space and weight, a very important factor in a ship. The second reason was that the difficulties in the way of proper lubrication of the cylinders became so great that it was found necessary to reduce the superheat to such an extent that the gain from it in economy became almost imaginary and which certainly did not warrant the expense of the installation of the superheater. The universal use of the compound engine on shipboard, therefore, very soon made the use of superheated steam impossible on steamships. It had been much less used in stationary practice, but with the gradually increasing pressure it also disappeared here.

It is true enough that the use of mineral oils very soon after this time became general, but our present day heavy lubricating cylinder oils were not known then, and, in addition, and this is much more important, the attention of all the foremost engineers of the world, working in this line, were now exclusively directed towards the improvement of the economy of the steam engine by means of the use of higher pressure and of the compound principle; they lost sight of the superheated steam, presumably, because of the many bad reports regarding its use. You all are aware of the fact that the improvement of the economy of the steam engine during the last thirty years of the last century was all due to the increasingly higher steam pressure and to the introduction of the compound and multiple expansion engines, if exception be made concerning the greatly improved mechanical details, especially with respect to valve gear and governor. But towards the end of the last century nearly all competent engineers agreed that the improvement due to the causes just mentioned had about reached its limit. The increased cost of making more than a triple or quadruple engine was not warranted by the very slight increase in economy due to an additional cylinder — at least with the high steam pressure then practicable. Because of the available material it had been impracticable—perhaps unprofitable — to design boilers for a higher pressure than, say, 250 pounds. It is due to this fact that the attention of the engineering world has within the last half dozen years increasingly been directed to the use of superheated steam as a means of improving the still lamentably low economy of the steam engine, and it is my opinion that the history of these years has conclusively shown that for the present, at least, the outlook in this direction is very much brighter than in any other. I realize very fully that Professor Lewicky, of the Polytechnic School of Dresden, Saxony, is perfectly correct when he states that all that is necessary in order to get a theoretical efficiency of the steam engine of 80 per cent is for the practical engineers of the world to supply material from which cylinders and boilers could be made which could properly resist pressures corresponding to a temperature of something like 1800 degrees Fahrenheit and also such temperatures. Unfortunately, there is at present no prospect that such a material will be supplied, at least in the near future, and, in fact, as stated above, the limit as to pressure has just about been reached for the present, and it is but natural that engineers should be looking out for other means of improving the economy of the steam engine which is still our greatest source of motive power. During all the years when it seemed that all interest in superheated steam had died out, there were still a few firm adherents working in this line. Among them must be specially mentioned Hirn, in Mulhouse, Alsace, his successor Schwoerer, and William Schmidt, in Germany. More than to any other it is due to these persons that at the present time superheaters have become a practical success. Schwoerer originated the ribbed cast iron superheater used extensively at the present time, whereas Schmidt used wrought iron coils and he was the first to use in practice highly superheated steam, the superheat often being more than 200 degrees Fahrenheit. Some of you will no doubt remember the sensation that was created when some eight years ago the results of a series of tests of a boiler and engine built especially for superheated steam by William Schmidt were reported in the technical papers. The tests had been conducted by Professor Schroeter of Munich, probably the highest authority in this branch in Germany, so that the results could not be doubted. Although the engine was quite a small one, yet it was shown that the consumption of steam had been only about 10.4 pounds per indicated horse power per hour, when using superheated steam; whereas the consumption of steam per brake horse power hour was only about 12.3 pounds, the engine developing 75 horse power. The statement of the consumption by an engine of a certain num-

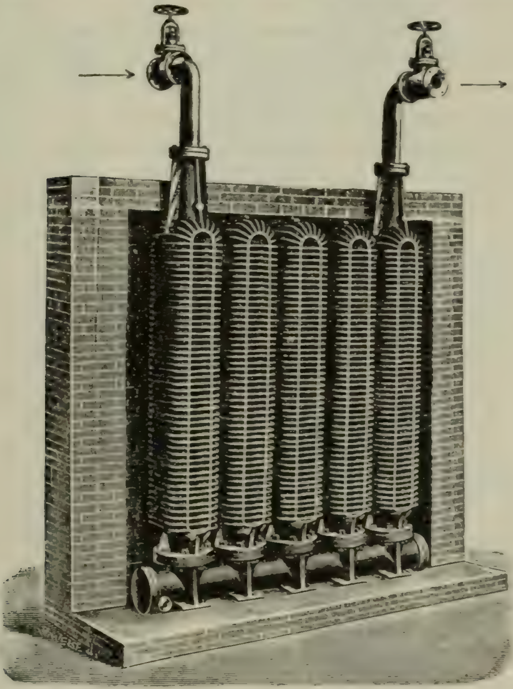

Fig. 1.
Schwoerer Type of Superheater.

ber of pounds of superheated steam per horse power per hour does not give the means for a true comparison of the performance of this engine with one using saturated steam. It is much more equitable to base the comparison on the consumption of coal or the number of heat units converted into work. In the test spoken of it was shown that the amount of coal used per indicated horse power per hour was only about 1.3 pounds, certainly an extraordinary result for an engine of only 75 horse power. The engine in question was a tandem compound, both cylinders being single acting; throughout of very original design and built especially for the use of highly superheated steam. The boiler which was also built and designed by Mr. Schmidt, was also very original and has since proved to be excellent in every way. As a result of this first test, Mr. Schmidt's engines became very popular and at the present time several hundred are running in Germany and adjacent countries.

As is well known there are two essentially different arrangements of the superheater with respect to the boiler. The most common is to install a coil in the boiler setting proper, through which the saturated steam taken from the top of the boiler is drawn on its way to the steam engine. If a high degree of superheat is wanted the coils must be installed in such a way that the hot gasses will strike them long before they have been cooled sufficiently to allow them to escape into the chimney. This arrangement has, as is well known, been extensively employed by the Babcock & Wilcox Company. On the other hand, if only a slight superheat is desired the coils may be placed so that the gases on their way from the boiler to the chimney will surround the coils. It may, however, be stated at this place that this last arrangement is usually not satisfactory, as the degree of superheat is so small that the gain in economy of the steam engine frequently does not warrant the installation of the superheater.

The second arrangement is to install an independent superheater with separate furnance, and a great many installations of this kind are found at present, especially on the continent of Europe. Many competent engineers have expressed their doubts as to the possibility of a gain in economy due to such installations, but repeated tests of a number of such plants have conclusively shown that these doubts were not warranted by the facts. When properly designed and run, such installations have invariably shown an economy as compared with the ordinary boiler and engine arranged for saturated steam.

Both wrought iron or steel, and cast iron are at the present time being used for superheaters. Because of the high temperature to which the material of the superheater will be raised, it is impracticable to have ordinary flange joints or couplings exposed to the hot gases. If therefore the superheater consists of a series of steel pipes of small diameter, they must be bent into coils, something like the ammonia pipes in a refrigerating machine. If on the other hand, the superheater is built of cast iron it is usually built along the lines in which Schwoerer originally made them; a number of large, straight cast iron pipes connected by flanged return bends, the flanges being placed in such a manner that they cannot

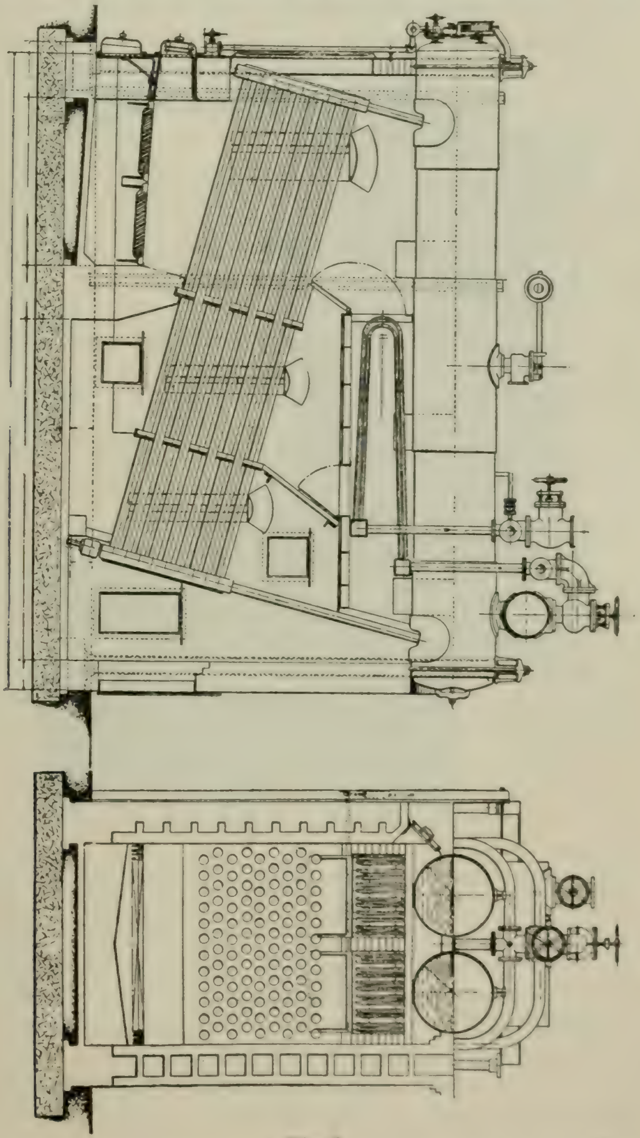

Fig. 2.
Babcock & Wilcox Water Tube Boiler with Wrought ron Superheater in the boiler setting.

be reached by the hot gasses, these pipes being also provided with a large number of external ribs so as to increase the heating surface. It is probable that the latter type will suffer less than the former type because of the action of the heat, both because its material is cast iron and because the walls of the pipes are quite heavy; but on the other hand, the heating surface in the former type will be much more effective—both because of the fact that the walls of the pipes are so thin and because the steam to be superheated is here distributed in a large number of small pipes, so that all steam is much closer to the hot gasses from which the superheat is to be derived. The difficulties which were encountered years ago with respect to the wearing out of the superheaters have now been overcome, as can be readily seen from the fact that there are now in service superheaters which have been used continuously for eight years and without any important repairs. The number of plants now running in continental Europe is several thousand, of which several hundred

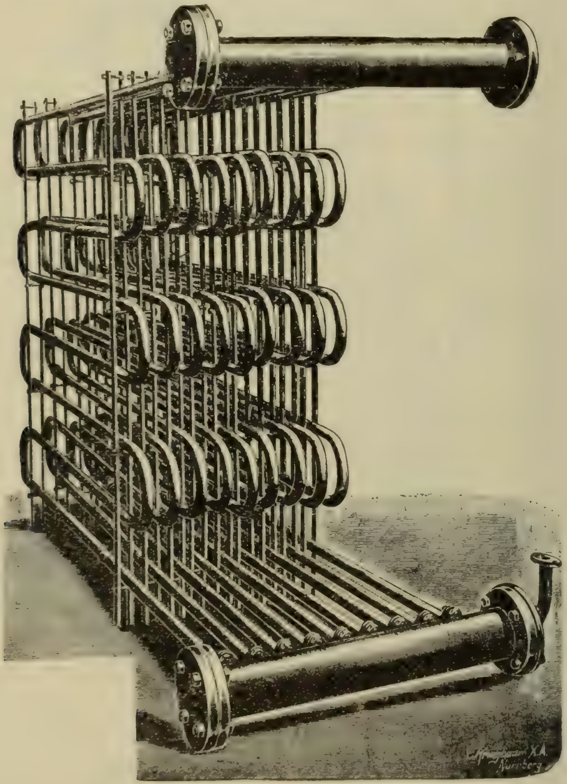

Fig. 3.
Superheater made by A. Hering, of wrought iron pipe with bends instead of elbows

are more than four years old, and any one familiar with the periodical technical literature, of Germany in particular, will agree with me that the published records of these plants so far as they can be found all testify to the fact above stated that the criticism, so often heard in former years that superheaters deteriorated very rapidly, is not true at the present time.

It was also to be expected that the use of such high temperatures in the engine cylinder would create new difficulties, not alone with reference to the proper lubrication of the same, but also and perhaps still more so, with regard to the great expansion of the parts of the cylinder itself. But it can also be stated positively that all these difficulties have been overcome. Just as in the gas engine where the temperatures are very much higher, and where these difficulties have been overcome by the proper design of the cylinder, so in the steam engine our modern engineers have found the proper way to proportion the various parts of the cylinder in such a manner that the expansion due to the high temperature does neither produce breaks in the casting nor leaks at the stuffing boxes. With reference to the lubrication it is only necessary to remind you of the existence of our modern heavy lubricating oils which made our modern gas engines possible. However these difficulties also explain the fact that William Schmidt previously mentioned, and who is more than anybody else entitled to the credit of the progress in the use of superheated steam during these late years, designed his first engines for superheated steam as single acting, probably in imitation of the only successful gas engine then existing, in which both the proper lubrication of the cylinder and the taking care of the expansion of the same had been satisfactorily accomplished. But at the present time, eight years since Schmidt first achieved success, we have both double acting gas engines and steam engines using highly superheated steam, and when properly designed and looked after, they run satisfactorily. What is more, in my mind at least, both the double acting gas engine and especially the double acting engine for superheated steam, will be the type of the future, if recent progress in these lines is to be any criterion for what is going to follow. The latest steam engine designed for superheated steam does not look very different to the uninformed from an engine using saturated steam of very high pressure, although a good many details may be different. In this connection it might be mentioned that the conclusive evidence of the experience of recent years is that Corliss valves are not adapted for the use of highly superheated steam and that consequently, we in our country, will have to modify the design of our most economical engines in a very essential part before we can use with profit, steam superheated to a degree which will show an improvement in economy to such a degree that it will warrant its use. As was intimated before, it is not alone the reciprocating steam engine proper which benefits from the introduction of superheated steam. The steam turbine so far as the experience goes at present, is destined it seems, to improve its economy to a higher degree even than the reciprocating engine. Experiments seem to show it, and the reasons for it advanced by the various investigators seem perfectly plausible. It would however, carry me too far to enter upon this question, and I would rather reserve this matter for a future day when I hope I shall be able to take up the steam turbine for discussion, the importance of the subject certainly warranting such separate treatment.

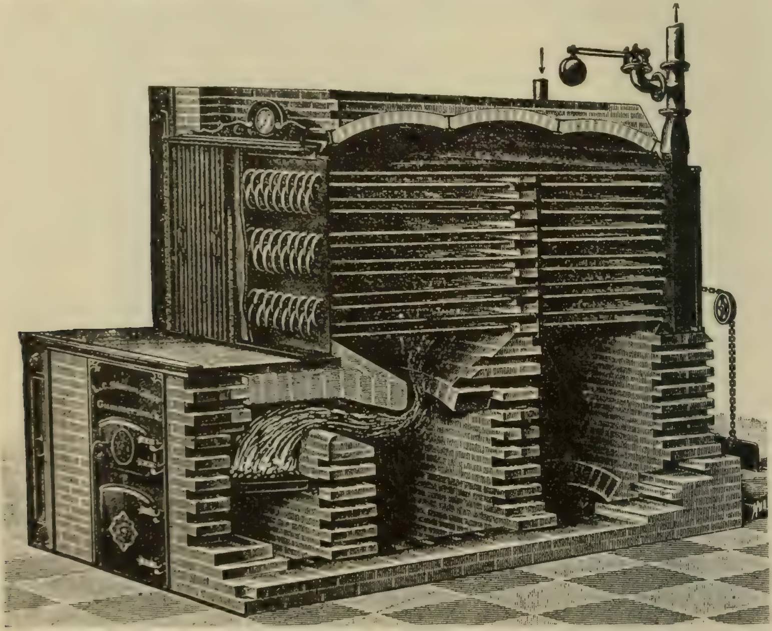

Fig. 4.
The Steinmüller Superheater, independently fired.

I am fully aware that so far my statements have been of a very general nature, and that I have given hardly any proofs for my absolute belief in the future of the use of superheated steam. Because of experiments conducted under my direction and because of the published results of thoroughly reliable tests I have become fully convinced, but in order to have any influence upon my auditors I shall need to quote some of the results upon which I have placed my faith. In what follows therefore, I propose to present to you some of the principal tests of engines using superheated steam and conducted by competent authorities, as well as the results of my limited experience in this direction.

The principal results of the test of Professor Schroeter of the Schmidt engine and boiler in 1895 and mentioned before, were as follows:

Size of Engine—$12\frac{1}{4}$ in. x $27\frac{3}{16}$ in. x $19\frac{1}{2}$ in., vertical, tandem, compound, making—

	1st Test.	2nd Test
Pressure	156.2	159.0
Brake Horse Power	61.72	62.18
Superheat, Degrees Fahrenheit	235.0	281.0
Steam in Lbs., per I. H. P., per hour	10.91	10.19
Steam in Lbs., per Brake H. P., per hour	12.61	12.34
Coal in Lbs., per I. H. P., per hour	1.36	1.26
Coal in Lbs., per Brake H. P., per hour	1.57	1.52
Per Cent of Heat Accounted for in Saturated Steam	65.0	63.7
Per Cent of Heat in the Superheat	6.9	8.2
Per Cent of Heat given to Feed Water	6.9	6.6
	78.38	78.5

Schroeter also reports on a similar engine, a little larger however, of 90 horse power, using superheated steam, which engine used only 9.95 pounds of steam per horse power per hour and 1.43 pounds of coal, certainly a very remarkable result for such a small engine.

In 1896 Professor Ripper of England published the result of a series of tests of a small Schmidt engine using superheated steam. The size of the engine was 7 1-16 x 11$\frac{3}{4}$; it made 180 revolutions per minute. He used both saturated steam and steam of different degrees of superheat in order to show the influence of the same.

	1.	2.	3.	4.	5.	6.
Steam Pressure, lbs., Absolute,	87.5	79.9	86.1	87.6	118.4	116.0
Temperature of Steam, deg. F.,	329.0	412.0	590.0	667.0	612.0	653.0
Degrees of Superheat, F	0.0	88.0	261.0	338.0	263.0	306.0
Indicated Horse Power	16.55	16.32	16.43	16.59	17.73	17.60
Lbs. of Steam per hour per Indicated Horse Power	39.33	34.66	21.48	19.13	18.84	17.58

It will be apparent from this table how rapidly the consumption of steam decreases with the increase of the superheat. With 338 degrees of superheat the number of pounds of steam used is not quite one-half of that used for saturated steam. In itself this performance of a single expansion, non-condensing engine, indicating only some 18 horse power and using less than 20 pounds of steam per horse power per hour is very startling.

In 1895 a large, triple expansion engine for superheated steam was installed in Augsburg, Bavaria. The old boilers were to be used and these could not carry more than 85 pounds pressure; but in connection with these Schwoerer superheaters were installed. Professor Schroeter conducted some very exhaustive tests on this plant, using both superheated and saturated steam in order to find out whether the moderately superheated steam showed any gain.

The dimensions of the engine were as follows:

Diameter of high pressure cylinder, 27½ inches.
Diameter of intermediate cylinder, 43⅜ inches.
Diameter of each of the two low pressure cylinders, 45⅜ inches.
Stroke of all pistons, 63 inches.
The engine made 60 revolutions per minute.
The main results of the tests are as follows:

	1.	2.	3.	4.	5.	6.
Indicated Horse Power	1180.5	1167.3	1127.8	1200.8	976.9	993.1
Steam Pressure (Gauge)	84.34	83.35	84.21	84.77	83.35	83.92
Temperature, Deg. F.	414.7	418.1	420.1	327.1	326.1	326.5
Degree of Superheat	87.9	92.0	92.3	....	......	......
Steam per Horse Power, Indicated, per Hour	13.06	12.68	12.05	14.31	13.55	13.22

Although the degree of superheat here is very moderate and the steam pressure very low, yet a decided gain in economy is shown.

A small Schmidt steam engine and boiler installed at Ascherleben, Germany, was also tested by Professor Schroeter. The cylinder had a diameter of 9⅞ inches and a stroke of 15¾ inches and was single acting; it made 150 revolutions per minute. A series of tests were made to show the influence of the cut-off and of various degrees of superheat. The most important results were as follows:

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
C.O. Per Ct., 1	16.1	22.9	35.0	41.1	48.0	22.5	15.7	23.4	36.5	26.1	24.3
St. Pr. 2	120.0	115.7	111.4	98.7	95.8	113.6	115.6	115.0	105.1	90.9	98.7
T. Deg. F. 3	669.0	671.0	673.0	680.0	689.0	667.0	574.0	588.0	597.0	491.0	408.0
S'ht. Deg. F. 4	319.0	324.0	328.0	343.0	354.0	321.0	227.0	241.0	206.0	160.0	71.0
Con. St. 5	17.85	17.59	18.03	17.54	18.03	17.45	18.86	18.52	18.93	23.08	27.68

1. Cut-off, per cent.
2. Steam Pressure, by Gauge.
3. Temperature, Degrees Fahrenheit.
4. Superheat, Degrees Fahrenheit.
5. Consumption of Steam per Horse Power per Hour.

The results conclusively show that the cut-off has very much less influence on the economy of the steam engine when running with superheated steam than with saturated, because there is very little change in economy between a cut-off of 16 per cent and one of 48 per cent, whereas it is probable that if the engine had been running with saturated steam this difference would probably have been at least 25 per cent. It is also well known that the interchange of heat between the steam and the cylinder walls is very rapidly reduced with increased superheat, so that, for instance, the heat absorbed by the walls during the admission period is almost zero when the steam is superheated from three to four hundred degrees. From some tests to be quoted later this will be very plain. But in passing it is perhaps worth while to call attention to the fact that the gain in economy due to the use of superheated steam is not alone due to the greatly reduced condensation in the cylinder, a fact which everybody recognizes, but also and perhaps in just as high a degree, to the greatly reduced interchange of heat between the walls of the cylinder and the steam while it is in the superheated state, this being due to the absence of water, which is always adhering to the walls when saturated steam is being used. From a number of carefully conducted tests it has been shown that the steam at the end of the expansion in the high pressure cylinder of a compound engine is still slightly superheated, if the superheat to begin with is from 200 to 300 degrees Fahrenheit. This is especially true if the cylinder is jacketed with superheated steam, and under such circumstances it would almost seem that it should be possible to eliminate all condensation from the high pressure cylinder, and at least reduce the heat interchange to such an extent that it hardly needs to be considered. In a single expansion cylinder or engine this would not be true, at least with the degree of superheat which is being used at present, as necessarily the change in

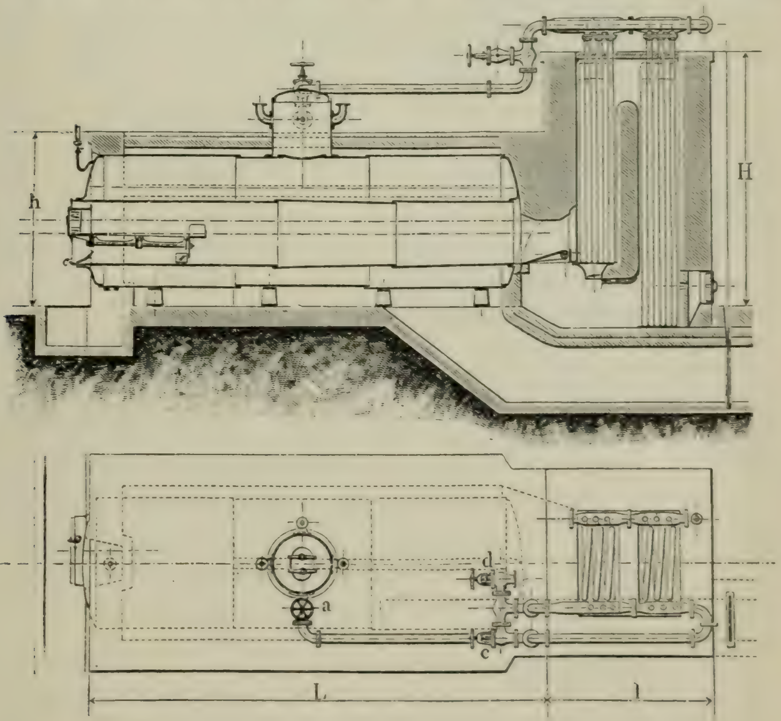

Fig. 5.
The Dingler Machine Co. Superheater of Wrought Iron Pipe, placed in the boiler setting.

temperature of the steam here would be very much greater. To prove these statements I submit the results of two sets of tests made by Professor R. Doerfel; one for a compound and one for a triple expansion engine.

Compound engine at Haunsdorf, Germany.

	1st Test.	2nd Test.
Indicated Horse Power	297.1	326.1
Steam Pressure, in Pounds	99.4	101.8
Temperature of Steam, Degrees Fahrenheit	337.1	495.0
Superheat, Degrees Fahrenheit	0.0	156.0
Pounds of Steam per I. H. P., per Hour	14.1	11.9
Heat Units per I. H. P., per Hour	286.0	257.0
Percentage of Heat Units contained in Steam given to Walls of High Pressure Cylinder during Admission Period	11.84	3.37
Percentage of Heat Units contained in Steam given to Walls of Low Pressure Cylinder during Admission Period	27.3	21.6

Triple expansion engine at Zwoden, Bohemia.

	1st Test.	2nd Test.	3rd Test.	4th Test
Indicated Horse Power	801.8	793.9	654.0	612.5
Steam Gauge Pressure, in Pounds		Average, 138.5		
Temperature of Steam, Deg. Fahrenheit	495.5	496.0	512.8	499.5
Superheat, Deg. Fahrenheit	135.9	137.0	153.2	140.1
Pounds of Steam per I. H. P., per Hour	11.07	10.95	10.75	10.95
B. T. U. per I. H. P. per Hour (degree)	237.8	235.5	232.8	236.1
Percentage of Heat contained in Steam given to Walls of High Pressure Cylinder during Admission Period	2.07	1.75	3.3	4.73

In the case of the compound engine, the direct comparison between superheated and saturated steam is made, and as will be seen the amount of heat given to the walls of the cylinder during the admission period is reduced to about one-fourth of what it is for saturated steam. For the triple expansion engine, it will be seen that the loss of heat is so small that it hardly needs to be taken into account in practical engineering. It should also be remembered that in both cases the degree of superheat is comparatively low, and that still better results can be expected and are in fact realized with a higher degree of superheat.

That the consumption of steam in both cases is very low should also be noticed, in fact a great deal lower than can be realized when saturated steam is used, but obviously if the degree of superheat had been greater, still better results would have been obtained.

Fig. 1 shows the superheater built by Boehmer Bros., Magdeburg, Germany. It is of the Schwoerer type; is made of cast iron, and in each pipe there is a partition extending from the bottom to near the top, so that the steam is forced to pass up the pipe on one side of this wall and down on the other. Each pipe has only one flange connection, so that they are free to expand upward. This superheater may be attached to almost any kind of a boiler, or it may be fired independently.

Fig. 2 shows the superheater built by the Babcock & Wilcox Co., also of the wrought iron type. It will be seen how, by means of two dampers, the hot gases may be prevented from reaching the superheater tubes. The amount of superheating surface in this arrangement is only sufficient to give a superheat of about 150 degrees Fahrenheit, when the boiler is working under ordinary conditions.

Fig. 3 shows one of the superheaters built by A. Hering, in Nürnberg. The material is wrought iron, and, as will be seen, all flange connections may be placed out of reach of the fire. This superheater has also been used in connection with a number of kinds of boilers—for instance, with water tube boilers, in which case it is placed above the drum.

Fig. 4 shows the Steinmüeller superheater as arranged for independent firing. It is also made of wrought iron and has especially been used in connection with water tube boilers, and several hundred of this type have already been built.

Fig. 5 shows the superheater built by the Dingler Machine Co., Zweibrücken, Germany. It is also made of wrought iron. In the figure it is plainly seen how, by means of the valve "c," the steam may be passed through the superheater or not, and also how the hot gases from the furnace may be prevented from reaching the superheater, by raising the damper at the rear of the furnace flue. As will be seen, the superheater is here divided into two parts for the purpose of utilizing the heat of the furnace gases to better advantage.

In studying the files of the technical periodical literature of continental Europe for the last few years, one finds the records of a very large number of tests of plants using superheated steam, and all the records so far as I have seen them, point in the same direction. Out of these I have almost at random picked out a few and after having transformed the results into English units, have given the main results. It would hardly seem that it was necessary to give any more, especially as these numbers must seem rather dry to the audience. But only a month or two ago appeared a series of articles in the *Zeitschrift des Vereins Deutscher Ingenieure* by Professor Schroeter, in which he gives the results of some remarkably interesting tests of a 250 horse-power, compound steam engine, built and installed in Ghent, Belgium. The tests were made for the purpose of determining the gain in economy due to the superheating of steam to various degrees and also to determine the influence of the variation in the load on the economy, using superheated steam. A series of sixteen tests were made with the utmost care and the results have been worked up in such a painstaking and complete manner that I have never seen its equal. As the results obtained from this engine are truly remarkable, in fact are so good that Professor Schroeter says in the first article that the economy shown is higher than for any other engine of its size so far tested, I have thought that it might be interesting to give the main results here. A series of six tests with saturated steam and different loads were first made, then five tests with superheated steam and for the same loads, with the exception of one, in which the engine was empty, and finally, five tests were made for the same load but with different degrees of superheat.

The engine was a tandem compound, having poppet valves and run-condensing. The cylinders were 12¾ inches and 22 inches in diameter, the stroke being 32½ inches, and it made 127 revolutions per minute. The steam pressure was kept as nearly as possible equal to 145 pounds by the guage during all the tests. The main results follow:

Number of Test—	1.	2.	3.	4.	5.	6. (empty)	7.	8.
Indicated Horse Power Developed....	316	277	222	170	118	22	318	272
Degrees of Superheat................							204.4	225,2
Consumption of Steam in Pounds per H. P. Indicated	13.43	12 64	12.08	11.48	11.84	13.52	10.71	10,25
Equivalent Consumption of Steam per H. P. Indicated....................							11.64	11.18
Gain in Economy due to Superheating, based upon Equivalent Consumption							.133	.121
Heat Units Required per I. H. P. per Hr.	278	261	250	241	245	280	241	231

Number of Test—	9.	10.	11.	12.	13.	14.	15.	16.
Indicated Horse Power Developed....	223	170	121	226	227	223	223	218
Degrees of Superheat................	225.9	223.9	223.9	43.7	97.7	151.7	221,2	310.9
Consumption of Steam in Pounds per H. P. Indicated....................	9.83	9.59	9.50	11.58	11.00	10.67	9.81	8.89
Gain in Economy on the Basis of Actual Consumption of Steam..............				.04	.09	.12	.19	.26
Equivalent Consumption of Steam per H. P. Indicated....................	10.74	10.43	10.36	11.77	11.44	11.33	10.69	10.01
Gain in Economy due to Superheating, based upon Equivalent Consumption	.110	.104	.125	.024	.051	.060	.113	.174
Heat Units Required per I. H. P. per Hr.	222	216	214	244	237	234	221	207

By equivalent consumption of steam is meant the reduction of the number of pounds of superheated steam used to the equivalent number of pounds of saturated steam of the same pressure, the reduction being made on the basis of heat units contained. The comparison of economy on this basis is consequently, perfectly equitable. The results as will be seen, are certainly startling, as I do not know of any engine of this size which has as high an economy whether running with saturated or superheated steam, the best results being 11.48 pounds for saturated and 10.01 (equivalent) for superheated steam. It is also shown in the article mentioned that in several of the tests the steam was still superheated, both at the end of admission and of expansion, confirming the general statements in this respect made before in this paper.

Finally I come to the tests with superheated steam which have been made under my direction in the Steam Engineering Laboratory in the University of Wisconsin. The experiments were made with a 50 horse-power cross compound Nordberg engine, provided with poppet valves. The steam used was taken from the general boiler house of the University; but before being delivered to the engine it was passed through a superheater of the Schwoerer type installed near the engine. The superheater was, therefore, of the independent type and was fired with coke during these tests. By means of discharging compressed air under the grate it was possible to get any desired superheat up to 200 degrees Fahrenheit, and also to keep it fairly constant. The engine is used exclusively for experimental purposes, the power being absorbed by a prony brake.

The tests were made for the purpose of determining the gain in economy by the use of superheated steam at different degrees. In all, eighteen tests were made; four with saturated steam, four with steam superheated on the averave of 50 degrees Fahrenheit, four of 100 degrees Fahrenheit, four of 150 degrees Fahrenheit and two of 200 degrees Fahrenheit. In the following will be given only the averages for each of the tests.

The cylinders are of 8-inch and 13-inch diameter and the stroke is 20 inches. During these tests it was run at 92 revolutions per minute.

	1.	2.	3.	4.	5.
Indicated Horse Power............	32.34	31.33	31.44	31.73	31.63
Brake Horse Power...............	30.27	30.31	29.76	30.35	30 31
Boiler Pressure, Gauge...........	90.1	93.9	92.0	97.6	95.6
Temperature of Steam, Deg. Fahr..	331.0	390.5	431.2	483.3	525.9
Degrees of Superheat.............		57.0	99.0	147.9	192.0
Steam in Pounds, Consumed per I. H. P. per Hour..............	22.78	20.89	21.22	19.1	17.05
Gain in Economy, in per cent, based on Consumption of Steam....		8	7	16	21
B. T. U. per I. H. P. per Hour....	416.00	391.00	402.00	373.00	338.00
Gain in Economy, in per cent, based on B. T. U.................		6	3	10	19

The table shows plainly the increasing gain in economy with the increasing degrees of superheat. This increase is necessarily not as large when based on the number of B. T. U. used as when based on the number of pounds of steam used, but the gain is very large in either case when the degree of superheat is 192 degrees Fahrenheit, as in the last tests. I have no doubt, however, that it will be noticed that the gain is smaller for 99 degrees than for 57 degrees. I do not believe that this represents the true state of affairs, and hence I conclude that an error must have crept in in one of these tests, or perhaps, in both of them, which error however, I have been unable to locate notwithstanding my best endeavors.

This paper has already exceeded the length which most persons can endure, and my conclusions, therefore, shall be very brief. It would seem from what has been stated before that it is time for our American engineers to pay a good deal more attention to the use of superheated steam than they have done heretofore. Some years ago we took a good deal of pride in the fact that our steam engines had shown the highest efficiency of any made in the world. This is not true any more; in this respect we have been left behind, just as we are behind at the present time in gas engine design and construction. This should not be so, but in order to regain our lost supremacy it will be absolutely necessary for us to arrange our boilers so that they can furnish highly superheated steam and to design our engines so that they can work properly with such steam. A beginning has been made in this country, but the movement must be accelerated and it is for this purpose that this paper has been written.

DISCUSSION.

Mr. Prisler—Why is the radiation in cylinders with moisture on the inside greater than when there is no moisture on the inside?

Prof. Bull—It has been found by experiment that the heat lost by the steam in an ordinary engine using saturated steam is always increased very rapidly with the adherence of the moisture to the metal surface. If you can keep that surface dry there is a very rapid decrease of condensation. Suppose you use supperheated steam, then first of all the steam has to lose a great amount of heat before it will condense, consequently for a long time no moisture will be found, and the rate of change will be greatly reduced. It is only where the moisture covers the walls that this rapid condensation takes place. These conclusions have, of course, only been reached by means of experiment.

Prof. Chamberlain—I wish to ask how the heat lost to the cylinder walls is determined?

Prof. Bull—By Stern's analysis.

Mr. Warder—In regard to the temperature you have shown in your tables of superheated steam—does that mean the increase above the temperature of the steam in the normal condition?

Prof. Bull—Yes. The temperature of superheated steam as used now is frequently more than 200 degrees above that of the saturated steam at the same pressure.

Mr. B. B. Carter—I would like to ask if any series of experiments on a large engine have been made, showing the effect of the superheating on the cutoff? In other words, after the steam is superheated, if there is also the accompanying gain that there is with saturated steam in the use of high expansions? That second table seems to indicate that the high cutoff, or high expansion, does not give any better economy when using superheated steam.

Prof. Bull—It hardly shows that. The table shows, however, that the consumption of steam at 16 per cent cut-off, or less than one-sixth, is only 17.85 pounds per horse power per hour for a 50 horse power engine, a truly remarkable result.

Mr. Carter—What I was trying to get at was whether, after using superheated steam, you also gain in economy by using the high expansion.

Prof. Bull—In the use of the compound engine you do, but not in the multiple cylinder. I am of the opinion that you do, although to a less extent than for saturated steam, if one is to judge from the table results of this test.

Mr. Priseler—Are poppet valves always used with engines using superheated steam, as regards European practice?

Prof. Bull—The European makers of high grade engines have had to abandon the Corliss valve because of the superheated steam. They are now using poppet valves, nearly all of them.

Mr. Carter—I suppose that includes all the slide valves.

Prof. Bull—Yes, to a great extent.

Mr. Arthur L. Rice—In that connection I will say that I was talking about a year ago with Mr. Hancock, of the Atlantic Avenue Station, in Boston, about using superheated steam with Corliss valves. He claimed that they had no trouble whatever with the gridiron valves on the McIntosh & Seymour engines up to 150 degrees of superheat.

Mr. W. L. Abbott—I have recently talked with Mr. W. P. Hancock, of the Boston Edison Co., and he says he compounds about 10 per cent tallow with the mineral oil, for cylinder lubrication, which I thought was peculiar, as tallow is not usually considered to be the proper lubricant to be used with superheated steam, but that is what he said he used.

Prof. Bull—It is quite possible that such things occur. It is very likely true that the gridiron valves do not give any trouble with superheated steam up to 150 degrees Fahrenheit. However, when you want to get real economy you want at least 200 degrees, or preferably a higher degree of superheat, and I am quite sure you will find difficulty with the Corliss valves under these circumstances.

Mr. Abbott—I would like to ask the Professor if he knows of cases where they run without any cylinder lubrication? I believe it is done to some extent in marine practice and in the navy. I think it is practiced on torpedo boats where they work the boilers very hard.

I would also like to anticipate Prof. Bull's next paper, if I may be permitted to do so, and inquire if superheated steam shows as much or greater advantage with the turbine than with the compound engine.

Prof. Bull—In answer to the last question, I would say that the advantages will be still greater.

Mr. McCulloch—Are any changes necessary in valves, fittings, etc., on account of the high temperature of superheated steam?

Prof. Bull—My experience has been that you can use ordinary rubber gaskets, although they must be of the very best.

Mr. McCulloch—Do you use any gaskets at all?

Prof. Bull—You use the very best gaskets. In regard to valves, I would say that there is no trouble whatever, although these also must be of the very best make.

Mr. McCulloch—Isn't there more difficulty in taking care of the expansion?

Prof. Bull—Oh, certainly. As far as the expansion is concerned, there must be made more allowance for that. There is a difficulty there. With a temperature increase of 200 or 300 degrees you have to allow for nearly double the expansion. I mentioned in my paper that the difficulty which the designers in late years first encountered was not as much from lubrication as from taking care of the expansion itself. The cylinder which uses saturated steam of 50 pounds pressure would have to be very differently designed from one that is going to use steam of 150 pounds pressure and superheated 200 degrees or more. It takes special care.

Mr. Priseler—In regard to what Prof. Bull has said—that American engine builders will have to build engines capable of using superheated steam, I think this is the case. I happen to know of one where an American builder lost an order for two Corliss engines because he could not guarantee them to run with superheated steam. That was for South Africa.

Mr. Finley—Do you not think that this country is behind others in gas engine design?

Prof. Bull—Yes, Germany and France and even Great Britain are ahead of this country in that respect.

Mr. Reichmann—Is there not some objection to the use of poppet valves on high speed engines?

Prof. Bull—I do not suppose you can use them on what we call high speed engines. They run up to 150, but that is the maximum.

Mr. Reichmann—What kind of valves are used for high speed engines when using superheated steam?

Prof. Bull—In superheated steam you probably have to get along with the piston valve.

Mr. Schaub—I am surprised that the discussion did not bring out some things that are being done in this country toward accomplishing the same thing. As I understand it, the saturation in the steam is removed by the superheating; so that if the entrained water has been removed, some of the difficulties due to the saturation will be overcome. I would like to ask if the Holley system does not accomplish this to a certain extent?

Prof. Bull—No, it does not. Superheated steam is used for the purpose of preventing the condensation in the cylinder after it has entered it. Even if the saturated steam entering the cylinder be perfectly dry yet you will certainly find that at the end of the admission there will be 30 per cent. of water in the cylinder.

Mr. Schaub—But the Holley system does take care of the condensation before you get the steam to the high pressure cylinder, does it not?

Prof. Bull—Yes, but it does not prevent the condensation after the steam has entered the cylinder, and it is this condensation which has been one of the main causes of the poor economy of the steam engine. The steam may enter the cylinder dry, but because of heat absorbed by the walls 30 per cent. may be condensed. Of course this 30 per cent. is not altogether lost, but certainly the greater part. If by means of using superheated steam this condensation may be reduced to 8 or 10 per cent., a very great gain in economy has been obtained.

Mr. Bley—I would like to ask Prof. Bull if he knows anything of a series of experiments by the Worthington people on one of the pumping engines in the city, either at Springfield ave. or Central Park, and what the result was?

Prof. Bull—No, I do not know anything about those experiments.

Mr. Chas. W. E. Clark, Jun. M. W. S. E., (*by letter*)—In this paper Prof. Storm Bull has presented to the Society information of great value, especially to those members who are daily confronted with the many problems which are brought about by the use of highly superheated steam. I am very sorry that Prof. Bull gives us no information as to the theory of superheated steam thermodynamically considered.

Without doubt, the engineers of Europe are far ahead of us at present in this matter, but if this problem is handled with the same energetic spirit and ability which have before this successfully conquered the many other serious problems that have presented themselves, I have no doubt it will be but a short time before we will be equal (if not superior) to the European engineers.

The American engineers are just awakening to the decided value of superheated steam as a source of energy, and I sincerely hope that this paper will awaken increased interest in the subject.

The steam turbine, which in a short time will doubtless supercede the reciprocating engine (especially for electrical generation) will do away with many of the difficulties which would otherwise be met with in the reciprocating engine. The main one of these is cylinder and valve lubrication.

The large boiler and engine manufacturers in this country are taking up the subject, and at present one finds no difficulty in obtaining good guarantees based upon the use of superheated steam. I think it is safe to say that all large plants that have been designed in the past year or two and all that will be designed in the future will be equipped with superheaters.

In a plant using reciprocating engines I do not consider it advisable to use a higher degree of superheat than 150 degrees Fahrenheit, while in a plant using steam turbines steam superheated as high as 250 degrees Fahrenheit may be used without danger of an increase in maintenance and repairs.

It seems quite remarkable that the Schmidt engine operates successfully with a superheat as high as 250 degrees or 300 degrees, this being due, I think, to the use of the double beat valve which engine builders in this country are beginning to use.

The main question yet to be solved is what degree of superheat will give the maximum economy. This will have to be solved separately for the different types of engines or turbines, as the radiation or internal condensation will vary with all the different types.

Some authorities claim that superheat in the exhaust is beneficial, while others advocate that just enough superheat be added to insure dry saturated steam in the exhaust. The latter, in my mind, is the correct solution of the problem. The determining of this point is very difficult in respect to the turbine. As yet no method has been devised for the collection of the necessary data to enable one to construct an entropy diagram of the turbine.

In speaking of efficiency one must not lose sight of the fact that pounds of water consumed per indicated horse power per hour do not necessarily imply the amount of coal.

In the matter of type of superheater, the independently fired superheater seems to me the best for all purposes, on account of the ability to control the degree of superheat, which is quite difficult when the superheater is installed in the boiler setting. In the latter case the superheat increased with the load on the boilers. As far as can be ascertained at present the wrought iron type of superheater has the same life as the cast iron type, with the increased efficiency on account of the better degree of conductivity of the metal.

The tests given in the paper are certainly all the more remarkable on account of the small size of the units.

I am at present engaged in the calculation of a table of "The Properties of Superheated Steam," and am pleased to submit to the Society a table of the "Specific Volume of Superheated Steam," which I have calculated from Schmidt's formulæ based upon Hirn's experiments.

Mr. A. Sorge, Jr., M. W. S. E. (by letter)—I have read with considerable interest Professor Storm Bull's paper on superheated steam, and in my opinion this is very timely and shows clearly the fuel economy to be obtained by this means.

In considering the subject, however, there is another phase of it which the Professor has not taken up. This is the practical operation of superheaters and engines connected with superheaters.

[illegible] F	0°	1°	3°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°	95°	100°	105°	110°	115°	120°	125°	130°	135	140°	145	150	155	160	165	170°	175°	180°	185°	190°	195	200°
165	2751	2904	2912	2918	2936	2954	2972	2990	3008	3026	3045	3062	3080	3098	3116	3134	3152	3170	3188	3206	3224	3241	3259	3277	3295	3313	3331	3349	3367	3385	3403	3421	3439	3457	3475	3493	3511	3529	3547	3565	3583	3600	3618
170	2676	2827	2834	2842	2859	2876	2893	2910	2928	2945	2963	2980	2998	3016	3032	3050	3067	3085	3102	3120	3137	3154	3172	3189	3207	3224	3242	3259	3277	3294	3311	3329	3346	3364	3381	3399	3416	3433	3450	3468	3486	3503	3520
175	2.603	2754	2761	2768	2785	2801	2818	2835	2852	2869	2886	2903	2919	2937	2954	2971	2988	3005	3022	3039	3055	3072	3089	3106	3123	3140	3157	3174	3191	3208	3225	3242	3259	3276	3293	3309	3326	3343	3360	3377	3394	3411	3428
180	2.535	2685	2692	2698	2715	2731	2748	2764	2781	2797	2814	2830	2846	2863	2879	2896	2912	2929	2945	2962	2978	2995	3011	3028	3044	3061	3077	3093	3110	3126	3143	3159	3176	3192	3209	3225	3242	3258	3275	3292	3308	3324	3341
185	2.470	2620	2626	2632	2649	2664	2681	2697	2713	2729	2745	2761	2777	2793	2809	2825	2841	2857	2873	2890	2905	2921	2937	2953	2969	2985	3001	3017	3033	3049	3065	3081	3097	3113	3129	3145	3161	3177	3193	3209	3225	3241	3257
190	2408	2558	2564	2570	2586	2601	2617	2633	2648	2664	2679	2695	2711	2726	2742	2757	2773	2789	2804	2820	2835	2851	2867	2882	2898	2913	2929	2945	2960	2976	2992	3007	3023	3038	3054	3069	3085	3101	3116	3132	3147	3163	3179
195	2349	2499	2505	2511	2526	2.541	2557	2572	2587	2602	2617	2633	2648	2663	2678	2693	2708	2724	2739	2754	2769	2784	2800	2815	2830	2845	2860	2876	2891	2906	2922	2937	2952	2967	2982	2997	3012	3028	3043	3058	3073	3088	3104
200	2294	2442	2448	2454	2469	2484	2499	2514	2528	2543	2558	2573	2588	2603	2617	2632	2647	2662	2677	2691	2706	2721	2736	2751	2766	2781	2795	2810	2825	2840	2855	2869	2884	2899	2914	2929	2943	2958	2973	2988	3003	3017	3032
205	2241	2389	2395	2401	2415	2429	2444	2458	2472	2487	2502	2516	2531	2545	2559	2574	2589	2603	2617	2631	2646	2660	2675	2690	2704	2719	2733	2748	2762	2777	2791	2805	2820	2834	2849	2863	2877	2892	2907	2921	2936	2950	2964
210	2190	2338	2344	2349	2363	2377	2392	2406	2420	2434	2448	2462	2476	2490	2504	2518	2533	2547	2561	2575	2589	2603	2617	2632	2646	2660	2674	2688	2702	2716	2730	2744	2759	2773	2787	2801	2815	2829	2843	2857	2872	2886	2900
215	2142	2289	2295	2300	2314	2328	2341	2355	2369	2383	2397	2410	2424	2438	2452	2466	2479	2493	2507	2521	2534	2548	2562	2576	2590	2603	2617	2631	2645	2659	2672	2686	2700	2714	2728	2741	2755	2769	2783	2797	2810	2824	2838
220	2096	2243	2248	2253	2266	2280	2293	2306	2320	2334	2348	2361	2374	2388	2402	2415	2428	2442	2455	2469	2482	2496	2509	2523	2537	2550	2563	2576	2590	2603	2616	2630	2644	2658	2671	2684	2698	2711	2724	2738	2751	2765	2778
225	2051	2198	2203	2208	2221	2235	2248	2261	2274	2287	2301	2314	2327	2340	2353	2366	2380	2393	2406	2419	2432	2445	2458	2472	2485	2498	2511	2524	2538	2551	2564	2577	2590	2604	2617	2630	2643	2656	2669	2682	2695	2709	2722
230	2.009	2155	2160	2165	2178	2191	2204	2217	2230	2242	2255	2268	2280	2294	2307	2320	2333	2345	2358	2371	2384	2397	2410	2423	2436	2449	2461	2474	2487	2500	2513	2526	2539	2552	2565	2577	2590	2603	2616	2629	2642	2655	2668
235	1968	2114	2119	2124	2136	2149	2162	2174	2187	2199	2212	2225	2237	2250	2262	2275	2288	2300	2313	2326	2338	2351	2363	2376	2389	2401	2413	2426	2439	2452	2464	2477	2490	2502	2515	2527	2540	2553	2565	2578	2590	2603	2616
240	1928	2074	2079	2084	2096	2109	2121	2133	2146	2158	2171	2183	2195	2208	2220	2232	2244	2256	2269	2282	2294	2307	2319	2331	2344	2356	2368	2381	2393	2405	2417	2430	2443	2455	2467	2479	2492	2504	2516	2529	2541	2553	2566
245	1.890	2036	2041	2046	2058	2070	2082	2094	2106	2118	2131	2143	2155	2167	2179	2191	2203	2215	2228	2240	2251	2264	2276	2288	2300	2312	2324	2336	2348	2360	2372	2385	2397	2409	2421	2433	2445	2457	2469	2482	2494	2506	2518
250	1.854	2000	2004	2009	2021	2033	2045	2056	2068	2080	2092	2104	2116	2128	2140	2151	2163	2175	2187	2199	2210	2223	2235	2246	2258	2270	2282	2294	2306	2317	2329	2341	2353	2365	2377	2389	2400	2412	2424	2436	2448	2460	2472
255	1819	1965	1969	1974	1985	1997	2009	2020	2032	2044	2056	2067	2079	2090	2102	2113	2125	2137	2148	2160	2171	2183	2195	2206	2218	2230	2241	2253	2265	2276	2288	2299	2311	2323	2334	2346	2357	2369	2381	2392	2404	2415	2427
260	1785	1931	1935	1940	1951	1963	1974	1985	1996	2008	2020	2031	2043	2054	2065	2076	2088	2100	2111	2122	2133	2145	2157	2168	2179	2191	2202	2213	2225	2236	2248	2259	2271	2282	2293	2305	2316	2327	2339	2350	2362	2373	2385
265	1753	1898	1902	1907	1918	1930	1941	1952	1963	1974	1985	1996	2008	2019	2030	2041	2052	2064	2075	2086	2097	2108	2120	2131	2142	2153	2164	2175	2187	2198	2209	2220	2231	2242	2253	2265	2276	2287	2299	2310	2321	2332	2344

FORMULA FOR ENGLISH UNITS

$S_v = 0.59276 \frac{441.9+T}{P}$ IN WHICH P= PRESS. IN LBS. PER SQ. IN.
S_v= SPECIFIC VOL. IN CU. FT. PER LB.
T= TEMPERATURE OF SUPERHEATED STEAM IN DEG. F.

SPECIFIC VOLUME IN CUBIC FT. PER LB. OF SUPERHEATED STEAM

CALCULACED BY SCHMIDT'S FORMULA BASED ON HIRN'S EXPERIMENTS

FORMULA FOR METRIC UNITS

$VP = 0.04683\ (263+T)$ IN WHICH: P= PRESS. IN KG PER SQ CM
V= VOL. OF 1 KG. IN CU METERS
T= TEMP OF SUPERHEATED STEAM IN DEG CELSIUS

During a somewhat protracted stay abroad I had occasion to study it more from the practical operative standpoint than from the theoretical standpoint of saving in fuel. Now the conditions in Europe are considerably different from those here. Over there the question of fuel saving is vastly more important than the question of labor saving. Labor is cheap and fuel is expensive. On the other hand, in the United States the positions are exactly reversed, and labor is expensive and fuel is cheap. In asking a great many of the operating engineers and also the people in charge of plants where superheated steam is being used in Europe, particularly in Berlin, I find that there are grave doubts in the minds of these people as to whether there is really any economy in the use of superheated steam when all conditions are taken into account. The question of repairs, the extra attention necessary, the more perfect lubrication required, and the difficulty due to this more perfect lubrication brings in items of expense even in Germany where the labor market is cheap which seem to make it a doubtful question as to whether superheated steam will ever show with reciprocating engines the saving which theoretically should be shown. I do not mean to say that in my opinion superheated steam is not the proper direction in which to work, nor do I mean to convey the opinion for one minute that I do not believe in the end it will show that it will be of great value and economy, but before taking it up as a finally settled proposition, which would seem to be the case from the large fuel economy shown in this paper, I think that the question of extra labor and care, the repairs and the greater attention required in plants of this character, together with the complication of machinery due to the use of superheated steam should be very carefully considered.

As stated above, I did not go into this question on the theoretical side the way Prof. Storm Bull has, but from the practical operative point of view my opinion is that up to date superheated steam has not shown itself of the enormous value which theoretically we would be led to expect. Furthermore, I fear that in this country it will show of even less economic value on account of the fact that the extra labor and attendance and care is much more expensive than it is abroad and therefore will more largely counterbalance the great saving which is undoubtedly shown theoretically due to the use of superheated steam.

CLOSURE.

Prof. Bull--With reference to the written discussion submitted by Mr. Chas. W. E. Clarke, I desire to state that an extensive European practice has shown that it is perfectly safe to go beyond the 150 degrees Fahrenheit of superheat for reciprocating engines, which Mr. Clarke considers the limit. Most plants constructed during the last five years in Germany use steam of at least 200 degrees Fahrenheit superheat, and the results, with respect to lubrication and maintenance, seem to have been very satisfactory. It is perfectly true that the economy realized by the use of superheated steam depends on the type of engine or turbine. But it is also a fact that all tests of all kinds of engines, as far as I have been able to find them in the technical literature, shows an increase of economy with an increase of superheat. That there is a limit, nobody will deny, but so far it seems that this limit has not been reached. It is certainly much beyond 150 degrees Fahrenheit.

How any authority can claim a benefit from having the exhaust steam superheated, I do not understand; it would seem that the heat corresponding to the superheat in the exhaust steam would be absolutely lost. This is of course only true for the single expansion engine. For a compound engine it would certainly be an advantage if the steam admitted to the high pressure cylinder was so highly superheated that the exhaust from this cylinder was still superheated to a considerable degree.

Mr. Clarke calls attention to the fact that "pounds of water consumed per indicated horse power per hour does not necessarily imply the amount of fuel." The paper itself speaks clearly on this subject, and Mr. Clarke will find that in several of the tests quoted the results have been reduced to pounds of coal or number of B. T. U. which amounts to the same thing.

As to the type of superheater, the question seems yet an open one, although it looks as if, in the last few years the wrought iron type has been the most popular one. Mr. Clarke is of course, perfectly right when he states that the independently fired superheater is much easier to control than the one installed in the boiler setting. But the question of control is only a part of the question, which must be decided when the choice is to be made. Both the cost of installation and the better utilization of the hot gases in the boiler must be taken into consideration.

As to the discussion by Mr. A. Sorge, Jr., I desire only to state that I am also fairly familiar with the practical results from the running of superheaters and of engines utilizing this steam in Europe, both from personal observation and from extensive reading of reports, and that I have found that neither the question of repairs nor that of extra labor is an important one. To be sure, some repairs are necessary, as in all kinds of machinery, and these repairs, together with the interest on the cost of installation and depreciation, should be taken into account. But these will be found to be small, compared with the annual saving. Where the extra labor is to be found, I do not see, except so far as repairs are concerned, so that the low price of labor in Europe has very little to do with the question.

As to the question of the cost of fuel, it certainly is intimately connected with the subject. It should be unnecessary to state that it would not pay to install a superheater next to a coal mine, where for instance, the coal costs a dollar or less per ton. But just as in Europe in a great many places, or in most places perhaps, so there are a great many places in the United States where the fuel is costly, and where it will pay to use superheated steam, and the most economical engines. It may, perhaps, be stated with profit at this place that a great many superheaters have been installed in Germany in the power plants of coal mines, and that the results have been highly satisfactory. But it should of course also be remembered that even at the mines in Germany coal costs a good deal more than at the mine here.

With reference to the lubrication, it was already stated in the paper that the difficulties in this respect have been entirely overcome. It is true that the very best oil must be used and that also a larger quantity is needed for superheated steam than for saturated. For highly superheated steam it has been found that about twice as much oil must be used to insure good lubrication.

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*At the New York meeting, 1903, Am. Soc. Mech. Engrs. a paper was presented by Prof. Jacobus on some recent tests of a compound engine using superheated steam. This is reported by abstracts in *Engineering Record*, Dec., 1903, p. 707, and the report indicates a saving of 13 per cent due to superheating.—Ed.

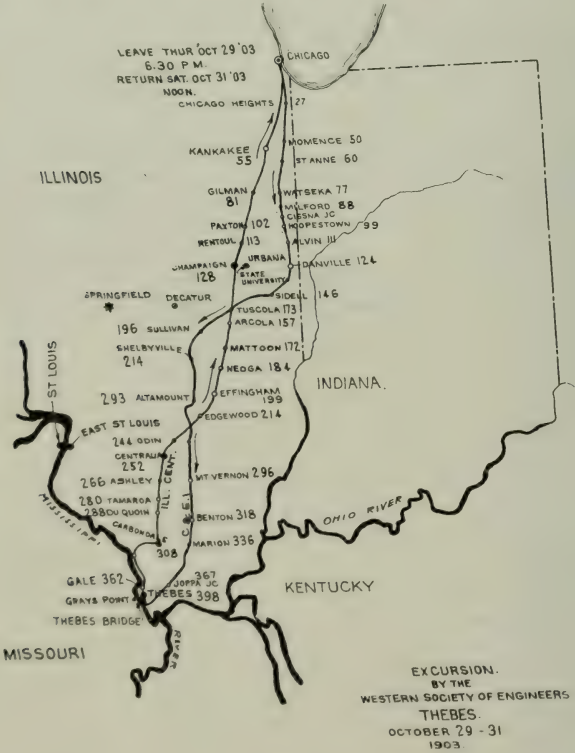
EXCURSION TO THEBES AND CARBONDALE, ILL.

October 29–31, 1903.

This trip was made by about 75 people (members of the society and their friends), leaving Chicago from the Dearborn Station of the Chicago & Eastern Illinois Ry., Thursday evening, October 29th, at 6:45, on a special train, consisting of a baggage car and three Pullman coaches—one of these being an observation car.

The first stopping point was Thebes, where the train arrived at 7 a. m., Friday, and where we were greeted with a glorious day. The ladies (numbering about fifteen), and a few gentlemen, were served with breakfast at the Thebes Hotel, the remainder of the party being served at the "Contractor's Camp."

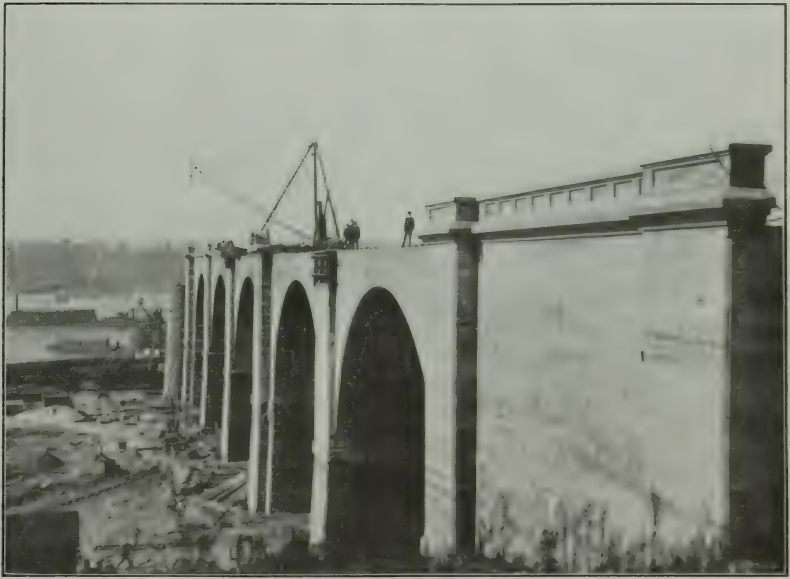
The forenoon was spent in the inspection and study of the Thebes Bridge over the Mississippi River, of which Mr. Ralph



Modjeski, (President, Western Society of Engineers) is Chief Engineer. An elevation of this bridge is shown on the accompanying plate, and the condition of the work is as follows:

MAIN PIERS.—Pier I completed. Pier II, foundation completed, masonry being laid; Pier III, pneumatic foundation now in progress; Pier IV, caisson being constructed; Pier V, foundation finished. The present stage of work illustrates exceedingly well the entire process of pneumatic foundations and heavy masonry construction.

CONCRETE APPROACHES.—East Approach, consisting of five 65-ft. arches and about 15,000 cu. yds. of concrete, practically completed. Concreting is being done on West Approach.



EARTH APPROACHES.—Heavy grading is in progress on both sides of the riveir.

After inspecton of the construction of the caisson for Pier IV, the party was conveyed to the opposite shore of the Mississippi river (the Missouri side), where further inspection was made of excavations for foundations of piers of the West Concrete Approach; also the concrete mixing and handling apparatus.

After spending considerable time in this inspection, the party recrossed the river, stopping on the way to view Pier V, partly completed; also Pier III, of which the foundation was then in progress, where several members descended into the working chamber of the pneumatic caisson. Pier II was also examined.

On the return of the boat to the Illinois side of the river, the party scattered, many ascending the hill to inspect the East Concrete Approach of the bridge.

The train left Thebes at 1 p. m. via the Illinois Central R. R. A delicate and bountiful luncheon was served en route, which, after the morning's outing, was appreciated and enjoyed by all.

Carbondale was reached at 3:30 p. m. Friday, where a stop was made to inspect the Ayer & Lord Tie Company's preserving plant the largest and most modern in its equipment in the world. (See Journal W. S. E., October, 1903, for paper by Mr. W. W. Curtis on "Timber Treating Plants.") Mr. W. W. Curtis, M. W. S. E., escorted the party through the works, explaining the plant and its operation. The party was shown the cylinders containing the ties under treatment, and other interesting parts of the plant, and it was stated that the discharged solution is collected in a well and afterward put through a purifying process and used again.

The train left Carbondale at 4:30 p. m. and arrived in a short time at the Big Muddy Bridge on the Illinois Central R. R. This is a notable structure of solid concrete, and was built by Mr. G. H. Scribner, Jr., from designs of Mr. H. W. Parkhurst, Engineer of Bridges and Buildings of the Illinois Central R. R., both being members of this Society. The bridge consists of three double-track concrete arches, each of 140 feet span and 30 feet rise. The total length is about 575 feet and the width is 32 feet; the structure contains about 12,000 cubic yards of concrete. A very complete description of this bridge and its construction, written by Mr. Parkhurst, appeared in "Engineering News" of November 12, 1903.

The next stop was made at Centralia, where supper was served at the Centralia House. The train left Centralia at 8 p. m., and the night was spent on the sleeper at Champaign. Breakfast was served at the Beardsley House, Champaign, Saturday morning, and the party left for Chicago at 8:30 a. m. to permit of a daylight inspection of the main line of the Illinois Central R. R. The party reached Chicago at 12 o'clock noon, October 31st, each one considering himself fortunate in having been able to participate in such a pleasant trip.

Thanks are due the Entertainment Committee for their successful management, and to the officials of the Chicago & Eastern Illinois R. R. and the Illinois Central R. R. companies for courtesies extended to the Society for this excursion. P. B. C.

DESCRIPTION OF THE THEBES BRIDGE.

The Thebes Bridge will cross the Mississippi River at Thebes. Four railroads, namely the Illinois Central and the Chicago &

Eastern Illinois on the East side, and the Missouri Pacific and the St. Louis & Southwestern Railway on the West side, are interested in its construction. It is to be a double track, high level structure. Its location is a particularly fortunate one, owing to the high bluffs on each side of the river which obviate the necessity of the usual long approach trestles.

The bridge will consist of a continuous steel structure of five spans. The central, or channel span, will be 617 feet long; the two spans on either side of the channel span will be 521 ft. 2 in. long; the two end spans will be 518 ft. 6 in. long; the two fixed spans on either side of the channel span will be 75 feet high between centers of chords; the suspended spans will be 55 feet high between chords at the center; the distance center to center of trusses will be 32 feet. There will be approximately 14,000 tons of steel in the structure.

The six main piers supporting the steel superstructure will be founded on rock; five of them, namely Piers I to V inclusive, are or will be founded by pneumatic process with wooden caissons. The Westerly pier No. 6 will be founded in open excavation, as solid rock is very near the surface of the river bottom.

The deepest pneumatic foundation will be at about elevation 250.00 or 50 feet below water.

The total height of the structure from the bottom of the lowest foundation to the top of the highest point on the superstructure will be 231 feet.

The chief difficulty encountered in the pneumatic foundations has so far been the irregular formation of rock, it being necessary to sink the caissons through bowlders, shale and hard rock, until the point was reached where the entire pier could rest on solid hard rock. This required a great deal of blasting inside of the working chamber.

The face stone of the piers will be of buff Romona Oolitic stone. The piers will be backed with Portland cement concrete. Granite is used for nose stones of the cut-water and for the bridge seats.

The bridge is approached at both ends by concrete arch approaches. There are five 65-ft. arches in the East Approach and six 65-ft. arches and one 100-ft. arch in the West Approach.

The foundations of these approaches are either on shale or on rock, as the case may be, and with the exception of one pier, have so far been in open excavation. One of the piers in the East Concrete Approach where a considerable amount of quick sand was encountered was founded by a concrete-steel caisson by means of open excavation. This foundation was quite successful and other foundations in the West Approach may be effected in the same manner.

The concrete in the approaches is of Portland cement. Its total amount is estimated at 35,000 cubic yards.

The East Approach to the bridge commences at the junction of the Illinois Central and Chicago & Eastern Illinois tracks 2.1 miles from the East end of the bridge. The total amount of excavation in this approach will be 260,000 cubic yards. The grade will be 0.5 per cent compensated on curves.

The West Approach begins at the junctions of the Southern Illinois & Missouri Bridge Company's tracks with the St. Louis & Southwestern tracks 1.9 miles from the West end of the bridge with a maximum grade of 0.5 per cent compensated on curves. The total excavation in this approach will be 300,000 cubic yards. The road bed on both approaches will be double track, ballasted and 85-lb. rails will be used.

The total length of the bridge proper, including concrete approaches, will be 3,807 feet.

The total length of the entire construction, including earth approaches, is 4.7 miles.

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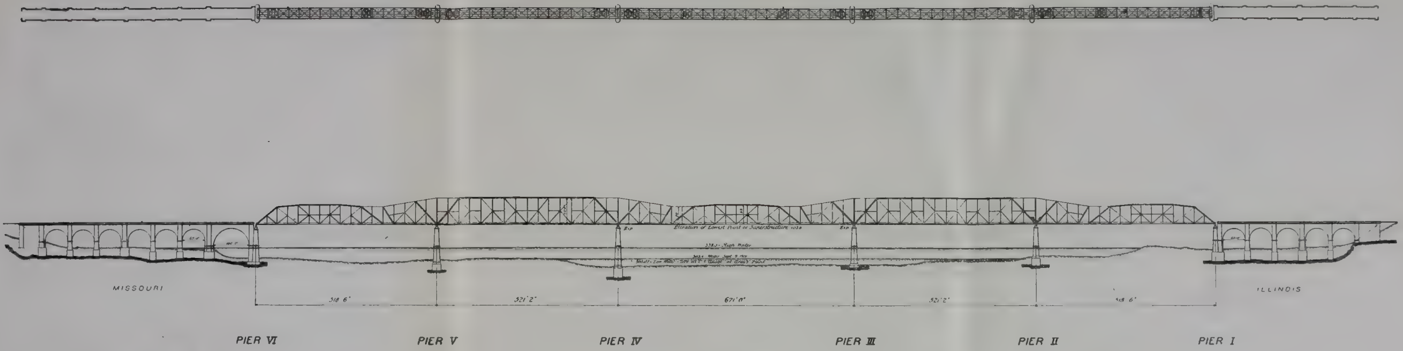
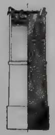
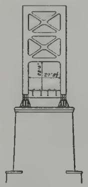
Vol. VIII. No. 6
Excursion to Thebes Bridge.

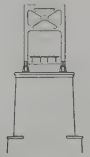




SECTION THROUGH CENTER OF ARCH SECTION THROUGH CENTER OF PIER



ELEVATION AT PIERS II III IV & V



ELEVATION AT PIERS I & VI

SOUTHERN ILLINOIS
AND
MISSOURI BRIDGE CO

GENERAL ELEVATION & PLAN
OF
THEBES BRIDGE

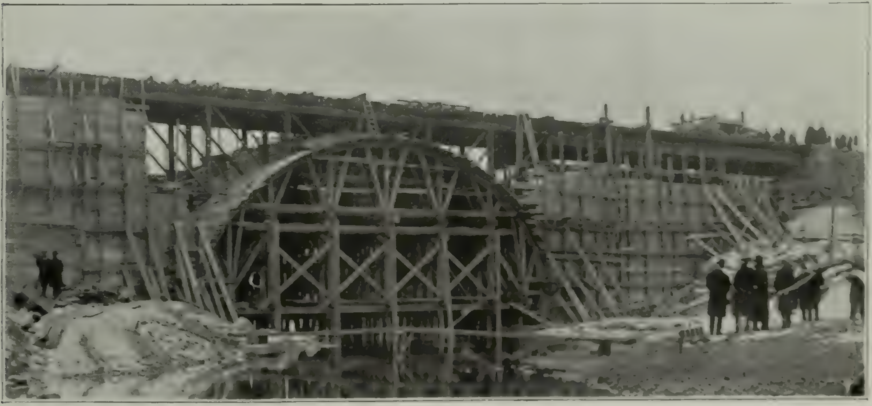
EXCURSION TO PLANO, ILL.

DECEMBER 5, 1903.

Through the courtesy of the Chicago, Burlington & Quincy R. R., a number of members and friends of the Western Society of Engineers had a special trip to Plano, Illinois, to see the construction of a concrete steel arch bridge over Big Rock Creek, the arch of which has a span of 75 feet. The concrete is reinforced by longitudinal and transverse corrugated square steel bars of the Johnson type.

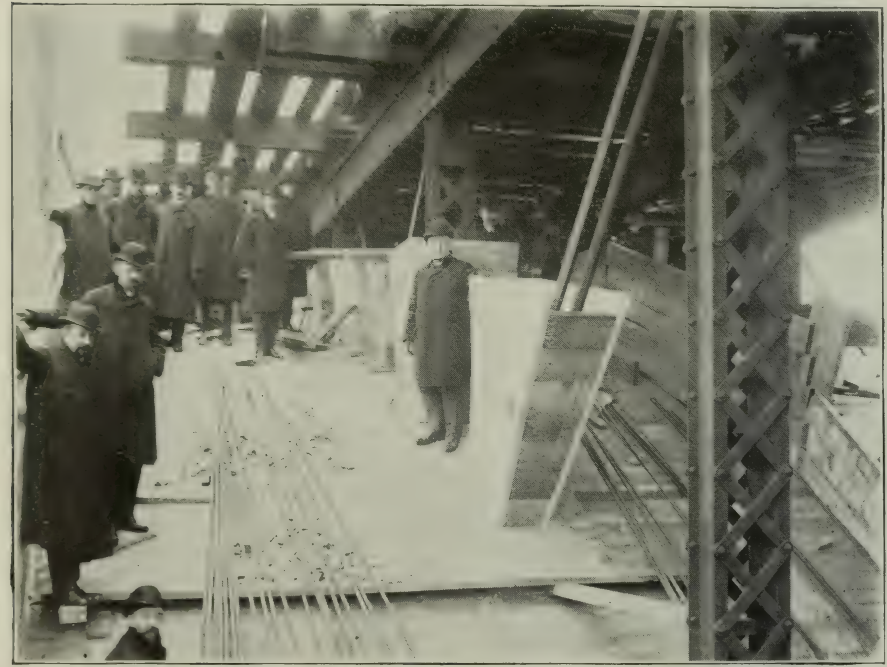
The party of nearly 150 left the Union Depot, Chicago, December 5th, 1903, at 11:30 a. m. on a special train provided for the purpose by the railway company. Lunch was served on the train soon after starting. The train stopped at the bridge, about half a mile north of Plano, that all might get out and make an inspection of the work in progress. After seeing the work, the train left about 3 p. m., and the visitors were back in Chicago before 5 p. m., very well satisfied with the results of the trip. Views of the work are shown herewith.

The old structure which is to be replaced by the concrete steel arch is a double track, steel deck truss of 95 ft. span, with deck plate-girder approaches at each end. The particular point of interest in the structure is the maintenance of the traffic on the old steel trusses during the construction of the cement arch. Openings are left in the concrete about sundry members of the steel trusses, through which these members can be withdrawn at the completion of the arch. The holes in the arch will be subsequently filled with concrete. After the completion of the concrete arch the track will be supported on timber bents and blocking, resting on the



VIEW OF FORMS AND CENTERING FOR CONCRETE STEEL ARCH BRIDGE—PLANO.

extrados of the arch while the steel work is being removed and until the filling is completed. The centering will probably not be removed before spring, to allow time for the setting of the concrete.



Concrete Steel Arch Bridge—Plano Under Construction.

The design for this bridge and the methods of executing the work were prepared in the engineers' office of the Chicago, Burlington & Quincy R. R., by Mr. W. L. Breckenridge, M. W. S. E., Chief Engineer, and Mr. C. H. Cartlidge, M. W. S. E., Bridge Engineer. Mr. G. H. Scribner, Jr., also of this Society, is contractor for the concrete work.

This structure is illustrated and described more in detail in "Railway Age," December 11, 1903, p. 816-17; "Railroad Gazette," December 11, 1903, p. 886 87; "Railway Review," December 12, 1903, p. 876-77.

ABSTRACT OF THE MINUTES OF THE SOCIETY.

REGULAR MEETING—November 4, 1903.

A regular meeting of the Society (No. 508) was held in the rooms of the Society Wednesday evening, November 4, 1903. The meeting was called to order at 8:15, with Past President Finley in the Chair and about 80 members and guests present.

The minutes of the regular meeting of October 7th and the extra meeting of October 21st were read and approved.

The Secretary presented a report from the Board of Direction, announcing the election of the following applicants into membership of the Society, at the regular meeting held November 3d :

Frank A. Windes, Winnetka, Ill., Active.
Valentine I. Smart, Chicago, Junior.
Oscar Seaberg, Chicago, Active.
Charles E. Sargent, Chicago, Active.
John O. Neikirk, Chicago, Junior.

Also that the following new applications had been received and referred to the Membership Committee for their usual consideration :

William R. Gillam, Chicago, Junior.
Albert Taylor Canfield, Kansas City, Mo., Active.
Henry H. Pendleton, Independence, Mo., Active.
Joseph Edward Bond, Chicago, Active,
Oscar F. Dalstrom, Chicago, Associate.
Francis J. Llewellyn, Chicago, Active.

A petition for amendment to the Constitution, for the purpose of increasing the Board of Direction (which was also presented at the last regular meeting of the Society and postponed until the November meeting) was again presented, and the Secretary explained that in case this amendment to the Constitution was adopted, a slight modification in the By-laws would be necessary, in accordance therewith.

A petition was also presented from the Committee appointed by the President for the purpose of looking into the matter of affiliation of the Chicago Electrical Association with our own Society, in which suggestions were made for amendments to the by-laws, providing for the creation of a section or sections "for the more convenient study and discussion of any special branch of engineering, as follows :

ARTICLE VII.

(Present Articles VII and VIII to be numbered VIII and IX respectively.)

SECTIONS.

SEC. 1. The formation of sections for the more convenient study and discussion of any special branch of engineering may be authorized by the Board of Direction upon the written application of ten or more active members, who shall state their reasons and define the purpose of the proposed section.

SEC. 2. Sections shall be known by names, clearly indicating the line of work contemplated.

SEC. 3. If more than three months elapse from the date of authorization of a section by the Board until it is in active operation, or if at any time it shall have less than twenty active members, such authorization shall be considered void.

SEC. 4. A section may make its own rules and regulations for the conduct of its business, and elect a Chairman, Vice Chairman and other officers, provided said rules and regulations do not conflict with the Constitution and By-laws, and are accepted by the Board of Directors.

SEC. 5. Meetings of Sections shall be open to all members of the Society.

They shall be in charge of officers of the Section, except that the Secretary of the Society shall act as Secretary for all meetings.

Mr. Andrews Allen moved to amend Sec. 3 of the above proposed amendment by striking out the word "active," where it occurs, so that a ections may be maintained by any members of any standing in the Society.

Mr. Condron moved to amend Mr. Allen's motion as follows: "A Section shall at no time include less than 10 active members, and 20 members altogether."

The motion as amended was then put to vote and carried in the affirmative.

Mr. Condron moved that the President of the Society be requested to appoint a committee of three to draft proper resolutions of thanks to the officers of the Illinois Central Railroad Co. and the Chicago & Eastern Illinois Railroad Co. for the tender of transportation and other courtesies to the members and guests of the Western Society of Engineers, on the occasion of their recent visit to the Thebes bridge, the Carbondale Tie Preserving Plant, and Big Muddy Bridge. The motion was unanimously carried.

Prof. Storm Bull, of Madison, Wis., then presented his paper on "Superheated Steam," which was afterwards discussed by Messrs. Priseler, Chamberlain, Warder, Carter, A. L. Rice, W. L. Abbott, McCulloch, Finley, Reichmann, Schaub, Bley, and Bull.

The meeting adjourned about 10 P. M.

EXTRA MEETING—November 18, 1903.

An extra meeting of the Society (No. 509) was held in their rooms Wednesday evening, November 18th. The meeting was called to order by President Modjeski at 8:15 P. M., with about 75 members and guests present.

The Secretary announced an inspection trip for the benefit of the members of the Society to see the actual construction of the double-track 75-foot concrete-steel arch at Plano, Ill., to be taken Saturday, November 28th.

President Modjeski introduced Mr. G. F. Culmer, of Chicago, who presented a paper on "Asphalt and Allied Hydro-Carbons," illustrated by lantern slides.

At the conclusion of its presentation, the paper was discussed by Messrs. Finley, Randolph, Warder, G. S. Rice, Pearce, C. S. Hall, Schaub, Tratman, W. E. Williams, E. H. Lee, W. D. Ball, Armstrong, and Culmer.

On motion of Mr. Armstrong a vote of thanks was tendered to Mr. Culmer from the Society for his very interesting paper.

The meeting adjourned at 10:30 P. M.

REGULAR MEETING—December 2, 1903.

The regular meeting of the society for December (No. 510) was held on the 2nd inst. The meeting was called to order at 8.15 p. m,, President Modjeski in the chair and about 55 members and guests present.

On account of other business before the society, the reading of the minutes of the regular meeting of November 4th, and the extra meeting of November 18th, was dispensed with.

The Secretary presented a report from the Board of Direction, of a meeting held November 30th, announcing the election of the following applicants for membership, under their respective grades:

William Carroll, Chicago, Active.
Robert F. Massa, Chicago, Active.
Ernest McCullough, Marshfield, Wis., Active.
William Krames, Kansas City, Kas., Active.
N. P. Frandsen, Chicago, Active.
William R, Gillam, Chicago, Junior.
A. T. Canfield, Kansas City, Mo., Active.
Charles Dunham, Chicago, transferred from Associate to Active.
Henry H. Pendleton, Independence, Mo., Active.
Oscar F. Dalstrom, Chicago, Associate.
Francis J. Llewellyn, Chicago, Active.
Percy Jones, Chicago, Active.

Also that the following new applications have been received:
Arthur S. Robinson, Elkhart, Ind., Active.

Carl J. Rhodin, Thebes, Ill., Active.
Perry L. Hedrick, Chicago, Active.
Stephen A. Wallace, Chicago, Junior.
Edward J. Schneider, Chicago, transfer from Junior to Active.

The Secretary also announced the result of the ballot on the amendments to the Constitution and By-laws, to increase the Board of Direction, as follows.

Amend the Constitution and amend the By-Laws:

Affirmative	171
Negative and irregular	8

Amendment carried.

Also the result of the ballot to amend the By-laws, to provide for the creation of sections for special lines of work, as follows:

Affirmative	161
Negative and irregular	7

Amendment carried.

The Secretary also announced that the result of the petition for nomination of candidates for the officers of the W. S. E. for 1904, was as follows:

For President—H. W. Parkhurst, C. L. Strobel, C. W. Hotchkiss.

For 1st Vice-President—C. W. Hotckhiss, A. Reichmann, A. Ziesing.

For 2d Vice-President—W. L. Abbott, W. C. Armstrong, E. B. Ellicott, C. F. Foster.

For 3d Vice-President—Prof. W. D. Pence, Lafayette, Ind.; Prof. A. N. Talbot, Champaign, Ill.; T. W. Snow.

For Treasurer—Andrews Allen, T. L. Condron.

For Trustee, for three years—John Brunner, A. Reichmann, E. R. Shnable, T. W. Snow, E. E. R. Tratman.

The Secretary stated that since the above nominations were made, Messrs. Strobel and Hotchkiss had requested that their names be withdrawn from the ticket for President; also Messrs. Ziesing and Reichmann from the ticket for 1st Vice-President: also Mr. T. L. Condron from the ticket for Treasurer: and Mr. John Brunner from the ticket as Trustee.

On motion of Mr. Finley, the report of the Board of Direction was accepted.

Mr. A. J. Mason, M. W. S. E., then presented his paper on "The Movement of Iron Ore on the Great Lakes," which was illustrated by lantern slides and by means of charcoal sketches.

The paper was discussed by Messrs. Liljencrantz, Seddon, Rainier, Pearce, Warder, Layfield and Mason.

The meeting adjourned at 10 P. M.

EXTRA MEETING—December 16, 1903.

An extra meeting of the Society (No. 511) was held in the Society's rooms, Wednesday December 16, 1903. The meeting was called to order at 8:30 P. M. by Past President Finley with about 50 members and guests present.

No business was brought before the Society but Mr. W. N. Pearce, M. W. S. E., was introduced, who read a paper on "Heating from a Central Station." This was illustrated by a number of lantern slides, and some charcoal sketches. There was some discussion of the paper from Messrs. Finley, Scott, Gifford and Pearce

Meeting adjourned about 10:30 P. M. J. H. WARDER, Secretary.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the issue of the JOURNAL for October, 1903, we have the pleasure to report the following gifts from donors named :

MISCELLANEOUS GIFTS.

Tratman, E. E. R.:
  Annual Report, Commissioner of Dams and Reservoirs, State of Rhode Island and Providence Plantations. Pam.
  Bulletins of the University of Wisconsin, as follows :
    No. 38. The Transcontinental Triangulation along the Thirty-ninth Parallel, by Hayford. June, 1900. Pam.
    No. 39. The Chemical Engineer, by Magnus Swenson. Pam.
    No. 40. Recently Improved Methods of Sewage Disposal, by J. B. Johnson, C. E. Pam.
    No. 42. An Experimental Study of the Corrosion of Iron under Different Conditions, by Hambruchen. June, 1900. Pam.
    Technology Quarterly and Proceedings of the Society of Arts, Mass. Institute of Technology. June, 1903. Pam.
    Report of the General Manager of Railways, Cape of Good Hope. 1901. Pam.
    "Administration Report on the Railways in India," by A. Brereton. 1901. Pam.
    Illinois Society of Engrs. & Surveyors. 18th annual report. 1903.
    Supplement to the List of Serials in Chicago Public Libraries, April, 1903, published by John Crerar Library. Pam.
    Proceedings, Master Car Builder's Association, Vols. 35 and 36, 1901-2. Cloth.
Wiley & Sons, New York, "The Elasticity and Resistance of the Materials of Engineering," by Burr. Cloth.
Whinery, S., New York, 2 pamphlets :
    " Report of Merchants Association of New York."
    " Passenger Transportation Service in New York City." 1903.
Lea Bros. & Co., Philadelphia, " Manual of Practical Hygiene," by Harrington. Cloth.
Spon & Chamberlain, at request of C. F. Allen, 2 books, flexible leather, " Railroad Curves and Earthwork," and " Field and Office Tables." 1903. By C. F. Allen.
Macmillan & Co., New York, at request of A. P. Hepburn, Secretary Sound Money League, New York, 1 vol., cloth, "History of Coinage and Currency in the United States, and Contest for Sound Money," by Hepburn, 1903.
Quincy, C. F., M. W. S. E., Chicago, 24 bound volumes :
    Cassier's Magazine, vols. 5 to 15 inclusive.
    Engineering Magazine, vols. 5 to 17 inclusive.
Ketchum, Milo S., University of Illinois, "Steel Mill Buildings." 1903. Cloth.
Haynes, A. M., M. W. S. E., Salt Lake City, one book, flexible morocco, " Curves of Civil Engineering." 1903.
Alderson, V. C., Pres. Colorado School of Mines, "The Twentieth Century Engineer." Pamphlet.
Corthell, Elmer L., M. W. S. E., " Report Upon Engineering Education." Pam.
Connecticut Agricultural Experiment Station, New Haven. " Protection of Shade Trees in Towns and Cities." Nov., 1900.
Sanitary District of Chicago, Trustees, " Report of Streams Examination for December, 1902." 1 vol., cloth.
Moore & Co., Chas. C., Engineers, San Francisco, " Steam Power Plants of the Pacific Coast." Pamphlet.

New Hampshire State Library, Trustees, "Reports for Period beginning June 1, 1900, and ending May 31, 1902. Vol. VIII. Part IV.

Morse-Boulger Destructor Co, New York, "Sanitary Disposal of Municipal Waste."

Beton & Eisen, Vienna, Austria, "Armored Concrete Lattice-Girder," by Max Emer. Pamphlet.

Colliery Guardian, London, "Ankylostomaisis; its cause, treatment and prevention." Pamphlet.

Official Directory of the Builders' and Traders' Exchange, Chicago, 1903. Leather bound.

American Society of Civil Engineers, "The House of the A. S. C. E., New York City."

EXCHANGES.

Railroad Commissioners' Report, Massachusetts, Returns of 1902.

Ewald, F. W., M. W. S. E., one book morocco, 32d annual report of Railroad and Warehouse Commission of Illinois, 1902.

American Railway Engineering and M. of W. Association, Bulletins Nos. 40, 41, 42, 43, 44 and 45, Proceedings, 1903.

Michigan College of Mines, Houghton, Year Book, 1902-3. Pamphlet.

Bond, Edward A., State Engineer and Surveyor, New York, 2 vols., cloth, "Report of the State Engineer and Surveyor, with supplement for 1902."

Association of Ontario Land Surveyors, Proceedings 11th annual meeting, February, 1903. Pamphlet.

Institution of Naval Architects, "Transactions, 1903." Cloth bound.

American Railway Master Mechanics' Association, J. W. Taylor, Secretary, Proceedings for 1900, 1901, 1902, 1903. Cloth.

Institution of Civil Engineers, London, Vol. CLIII, Proceedings, 1903. Pamphlet.

Bureau of Mines, Ontario, 12th report, April, 1903. Pamphlet.

Baker, Prof. Ira O., M. W. S. E., Champaign, Ill., The Technograph of the University of Illinois, No. 17, 1902-3. Pamphlet.

North East Coast Inst. of Engineers and Shipbuilders, New Castle on-Tyne, Transactions 1902-3, Vol. XIX.

Smithsonian Institution, "Annual Report, Board of Regents," 1902.

American Water Works Association, Proceedings 23d annual convention, 1903. Pamphlet.

Canadian Society of Civil Engineers, Vol. XVI, Parts 1 and 2, 1902. 2 pamphlets.

American Electrochemical Society, Transactions, 1903, Vol. 4. Cloth.

Master Car Builders' Association, Proceedings, 1903, Vol. 37. Half roan.

Wisconsin State Board of Health, Dr. U. O. B. Wright, Secretary, 19th report of the State Board of Health. Cloth.

W. S. Blatchley, State Geologist, Dept. Geology and Natural Resources of Indiana, 26th annual report, 1901.

City Engineer, Milwaukee, "Annual Report, Board of Public Works, Milwaukee, 1902." Pamphlet.

GOVERNMENT PUBLICATIONS.

Department of the Interior, U. S. Geological Survey, pamphlets:

"Production of Chromite or Chromic Iron Ore in 1902." Pratt.
" " Lithium in 1902."
" " Fluorspar and Croyolite in 1902." Pratt.
" " Asbestos in 1902." Pratt.
" " Barytes in 1902." Pratt.
" " Phosphate Rock in 1902." Struthers.
" " Quicksilver in 1902." Struthers.
" " Borax in 1902." Struthers.
" " Copper in 1902." Kirchhoff.
" " Talc and Soapstone in 1902." Pratt.
" " Platinum in 1902." Struthers.
" " Nickel and Cobalt in 1902." Pratt.
" " Abrasive Materials in 1902." "
" " Precious Stones, in 1902." Kunz.
" " Lead." Kirchhoff.

"Oil Fields of the Texas-Louisiana Gulf Coastal Plain." Hayes and Kennedy.
"Geographic Tables and Formulas." Gannett.
"Catalogue and index, Publications of the U. S. Geological Survey, 1901-3." Warman.
"Results of Primary Triangulation and Primary Traverse, 1901-3." Gannett.
"Manufacture of Coke in 1902." Parker.
"Mineral Resources of Mt. Wrangell District, Alaska, 1903."
"The Vermilion Iron Bearing District of Minnesota," Vol. XLV. Cloth. Monograph. Atlas for same.
Bulletin 211, "Upper Carboniferous Rocks of the Kansas Section."
Bulletin 217, "Notes, Geology of S. W. Idaho and S. E. Oregon."
"Drainage Modifications in S. E. Ohio and adjacent parts of West Virginia and Kentucky."
"Water Supply and Irrigation Papers, Nos. 80 to 86 inclusive."
Dept. of Interior, Bureau of Education, "Report of Commissoner, 1902." Vol. 1.
U. S. Department of Agriculture, Bureau of Forestry:
"Diminished Flow of the Rock River in Wisconsin and Illinois." Schwarz. Pamphlet.
"Forest Lands in Hampton and Beaufort Counties, South Carolina." Sherrard. Pamphlet.
"Report Irrigation Investigations for 1902." Pamphlet.
U. S. Department of Agriculture, Elwood Mead, Chief of Irrigation Investigations, "Plans of Structures in Use on Irrigation Canals in the United States." Pamphlet.
Library of Congress, Washington, D. C., "Copyright in Canada and Newfoundland." Pamphlet.
Interstate Commerce Commission, "15th annual report on the Statistics of Railways in the United States, 1902."
Mann, James C., M. C., Washington, D. C., "Yearbook U. S. Department of Agriculture, 1902."

TRADE CATALOGUES.

Jeffrey Mfg. Co., Columbus, Ohio, "Jeffrey Coal Washing Machinery."
Jeffrey Mfg. Co., Columbus, Ohio, "Power Drills for Rock and Coal." Pamphlet.
Ingersoll-Sergeant Drill Co., New York, "Air Compressors," Catalogue 33 B, 1903.
Riehle Bros. Testing Machine Co., Philadelphia, "Supplementary Sheets for Catalogue A."
Goheen Mfg. Co., Canton, Ohio, "Galvanum."
Hollister Bros., Chicago, one book, boards, "Samples of printing, catalogues and circulars, with engravings."
United Telpherage Co., sundry pamphlets.
Power Specialty Co., New York, "The Foster Patent Superheater."
American Steam Superheating Co., Boston, "The American Superheater."

BOOK NOTES.

History of Coinage and Currency in the United States, and the Perennial Contest for Sound Money. By A. B. Hepburn. The Macmillan Co., 1903. Price $2.00.

The title of this work, and more especially its sub-title, renders almost unnecessary the statement following the name of the author, which indicates not only his collegiate degree but the fact that he is a banker of high standing and of broad experience.

The position of the author on the currency question is unmistakably outlined in the introductory chapter, wherein he unequivocally ranges himself on the side of Alexander Hamilton and the Federalists, and throughout the book in his endorsement of the first and second United States Bank—of the National Banking System as introduced during the Civil War—and his advocacy of the single gold standard, he shows that "sound," to his mind, has but one synoym, and that this is, "solvent."

The history of the currency of the American people is traced from the Colonial to the present day, and the various aberrations by which the popular fancy (one may not say the popular mind) has been from time to time caused to swerve from the "narrow path" are duly noted, and it is patent to the casual reader even, that an honest attempt is made to present a fair picture of the situations as they existed at the successive periods of the country's growth, and of the difficulties which have at different crises beset the people, giving birth to financial heresies, which were heralded as panaceas by empirics, and were swallowed by the ignorant as cures for all ills, no matter from what sources they sprang, and, after a longer or shorter period of exhilaration, were followed by the usual consequences of the indiscriminate indulgence in patent medicines, a sickening attack of nausea, and a succeeding state of general collapse.

The proneness of men of one generation to repeat, with slight variations, the economic errors of their predecessors, as illustrated by the vacillations in the attitude of the government toward banks, gives rise to the reflection that after all, advances in any given department of information are very slow, and never proceed in direct lines, but rather in curves, showing partial relapses after each ascent, and the total progress measured only by the sum of the several gains.

As early as 1790 Hamilton pointed out the very defects of a sub-treasury system which now are so strongly marked—mainly the withdrawal of currency periodically from circulation, and to offset which, successive Secretaries of the Treasury, down to the present incumbent of the office, have racked their brains to invent new devices. Yet, after chartering two United States Banks, with an interval between them, to act as fiscal agents of the government and furnish currency to the people, a sub-treasury system was inaugurated in 1840, only to be repealed in the following year; again authorized in 1846, and continued ever since, but with varying methods as to strict or liberal construction of the law governing the same, according to the financial, and often (as plainly shown by the author) the political leanings of the administration. And so, more than a century after Hamilton, as Secretary of the Treasury, pointed out its defects we find James H. Eckels, when Comptroller of the Currency, compelled to describe the sub-treasury system as "an institution based upon false principles in economics, and which in every part violates correct banking methods and principles."

The alternating phases of good, indifferent, and vicious paper money endured in this country under issues by the U. S. Bank, the state banks with and without security, the "wild cat" and "stump-tail" varieties, and even the unauthorized issues by private individuals passing current as a medium of exchange from time to time, are well portrayed, and a perusal of the chapters on this prepares one to understand why the Government issues of greenbacks and the National Bank Notes since the era of the Civil War were so welcomed by the people as a relief from the dangers and anxiety incident to the paper money which preceded them.

The introduction and gradual expansion of the Clearing House System, from the establishment of the New York Clearing House in 1853, and the steadying influence exercised by the system in times of storm and stress, is satisfactorily outlined, and the accompanying tables furnish excellent statistical information.

The wavering policy of the Congress and the Executive on the legal tender question; and the see-sawing of the Supreme Court in its decision of 1870, which declared them unconstitutional; of 1872, which declared them constitutional, but "seemed to base its approval of the act upon the necessities growing out of the war;" and that of 1884, which asserted "that the power to issue legal tender notes in time of peace as well as in time of war, was accorded by the Constitution," are effectively chronicled; and as if to take the reader into his confidence as to his own views upon the subject, the author on the next page quotes from Secretary McCulloch's report for 1884, on the subject of legal tender notes, as follows: "They are not money, but merely promises to pay it, and the Government must be prepared to redeem all that may be presented or forfeit its character for solvency."

There is a full review of the various coinage acts, both as to gold and silver coins, showing the fluctuations of the standards; and in discussing bi-metalism, the single gold and the single silver standard, we find Chairman Dunham of the Ways and Means Committee of the House as far back as 1853, quoted to the effect that "Gentlemen talk about a double standard of gold and silver as a thing that exists, and that we propose to change. We have had but a single standard for the last three or four years, that has been, and now is, gold. We propose to let it remain so, and to adapt silver to it, to regulate it by it." Yet it was not until 1873 that the act to demonetize the silver dollar was passed by Congress, and not until the country had passed through the long agony described in the book terminating in 1890, that a law was finally enacted, declaring the gold dollar the standard of value.

The book shows numerous evidences of haste in its final make-up, and some errors which, in a work of this class, are inadmissible, such as the date "1871" for "1781" on page 58; "1851" for "1815" on page 78; 81,000 for Cooper in "1884" in place of "1876" on page 240; and all of which should be corrected in a future edition, but, as a book of reference, for its careful collection of data, its agreeable presentation of them, its apparent aim to allow the reader impartially to arrive at his own conclusions, notwithstanding the ever-visible ardent advocacy of his own convictions, it is bound to be valuable, while the statistical tables, bibliography and appendix covering valuable reports, entitle it to a place on the shelves of any library aiming to aid the searcher in the fields of finance and currency. J. S.

Chimney Design and Theory. By William Wallace Christie. D. Van Nostrand & Co., New York, 1902. 8vo, cloth, 192 pages, including index, 53 illustrations. Price, $3.00.

In this volume the author gives interesting historical, theoretical and practical information about chimney draft theory and chimney design.

The historical features extend in brief outline from 1368 A. D. to the present time.

In the chapter on chimney draft theory and rates of combustion, the author gives some useful tables on the following subjects:

Heights of chimneys and corresponding heads for burning given amounts of coal.

Density of weight per cubic feet of air at different temperatures.

Draft pressure in chimneys per 100 feet of height.

Draft pressure and velocity of gases in chimneys and in any others upon the rates of combustion.

The author makes comparisons between many different formulæ giving the H. P. of chimneys.

In the chapter upon Chimney Foundations, the author gives data of the building law requirements of different cities, and describes the construction of a few existing chimney foundations.

The author also gives a table of the coefficient of expansion of masonry and a table of compressive tests of stones.

In the chapter upon the Theory of Steel Chimneys, the author gives tables of Strength of Wire Ropes, Weight of Circular Boiler heads, Moment of Resistance of hollow cylinders and proportions for riveted joints.

The author outlines the theory of the stability of a Self-Supported Chimney, and explains the calculations necessary for the design of the same. In the formulæ for the stability of chimneys, the author does not make matters quite plain and his method of treating the subject, while perfectly correct, is confusing.

The author's method of finding the stress in the foundation bolts of a self-supporting stack is to me incorrect, or at best only an approximation of the actual conditions that exist.

In an article in the "Engineering Record" of June 6th, 1903, Mr. R. E. Newton of Milwaukee, Wisconsin, gave what I consider the best solution to this problem.

The author presents cuts and data upon existing steel chimneys.

In the chapter on Brick Chimneys, the author outlines the theory of the stability of brick chimneys.

The author states on page 89 that "For a chimney whose axis is vertical, the moment of stability is the same in all directions." This is true for a round chimney only.

The author gives cuts and data of a number of existing brick chimneys, also citing a few chimney accidents.

There is a chapter on house chimneys, also one on lightning protection.

C. W. CLARKE.

Furnace Draft. Its Production by Mechanical Methods, by W. W. Christie, Mem. A. S. M. E., Patterson, N. J. Published by the author. 4x6 inches, 44 pages, Price, 50 cents.

In submitting this little monograph to the engineering profession, the author presents some valuable data on furnace conditions with mechanical draft, whether obtained by fans or steam jets, and also of induced draft as by a tall chimney. From the general tenor of the remarks on and discussion of this subject, the author indicates his preference to the production of draft by mechanical means, though this view of the subject is not greatly insisted upon. The author claims to be unbiased, and does not hesitate to show up the bad as well as the good points of the different systems employed. The author also dwells upon the fact that no one device or system is good under all conditions, and that generally the welfare and economical working of any steam plant can be greatly benefitted by the services and advice of a qualified consulting engineer. While there appears to be some misleading comparisons between mechanical and natural drafts; and many readers may differ from the author in his statements, yet it is to be frankly stated that there is a good deal that is valuable between the covers of this little book. This refers particularly to sundry tables on boiler tests, gas analysis, steam consumption of steam jets and blowers, etc. etc. C. C.

Curves of Engineering. The Transit Man's Pocket Companion. By A. M. Haynes M. W. S. E., Denver, Colo. 1903. 4 x 7 inches, Morocco, flap, 117 pages. Price, $2.50.

This subject of railroad curves has been considered by several writers within the last few years, and an extensive treatment of the Transition Spiral has been published in the pages of this Journal. There is a new book on the subject of curves by a member of this Society, as noted above, which deserves some attention. The first point in this work is the substitution of arc measurements, in place of chord measurements as used heretofore, and the author defines circular curves and gives a method of projecting curves on the ground, staking out, establishing transit points, etc. He describes the tools to be used for linear measurement, and manner of using, including measuring on slopes and curves. Angular measurements follow, with instructions on points to be noted, including the establishment of a true meridian by observation on polaris, and of field work. Transition Curves occupies one chapter, and others are given to platting turnout curves and vertical curves. As a pocket companion to an instrument man in the field, the main body of the book is occupied with sundry tables and diagrams, and examples of transit notes and how kept. Table IX, covering 72 pages, give functions of a one degree curve conveniently arranged. The paper and typography of the book are excellent. W.

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NOTICE

From the dues of each member, $2.00 is set aside as a subscription to the Journal.

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